Energy Tidbits

Will Markets See Iran's No Israeli Embassy is Safe Anymore as Taking Direct Military/Missile Attack on Israel Off the Table?

Produced by: Dan Tsubouchi

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SAF Group created transcript of Energy and Natural Resources Minister Jonathan Wilkinson with CTV Question Period host Vassy Kapelos on March 31, 2024. https://www.ctvnews.ca/politics/feds-not-interested-in-investing-in-lng-facilities-energy-minister-1.6828149

Items in "italics" are SAF Group created transcript

at 7:15 minute mark, Wilkinson *"As I said, the commitment has always been that the money that's collected will flow back, it will flow back in the near-term. At the end of the day it is important that small businesses are, have an ability to address the issues associated with paying the price on pollution, that there is a rebate, and certainly those that have actually accumulated with respect to small businesses, will be returned."*

Kapelos *"When does that happen, what does near-term mean? Respectfully, Minister".*

Wilkinson "*Well as I say, it will be over the coming months. I don't have a specific date, and certainly you are very welcome to ask that question to the minister of finance, who is the minister who is actually responsible for administering it, but it will be in the near-term."*

Kapelos *"I will do so. I have just one other issue to ask you about that is most distinctly in your purview and that's around LNG. I spoke to Greece's Prime Minister on this program last year and he said that Greece would, quote unquote, 'absolutely want Canadian LNG as Europe does try to displace Russian gas'. Does that matter to you?"*

Wilkinson *"Well sure, and to be honest, that there is a lot of LNG development going on, largely on the west coast of Canada, with LNG Canada, with Woodfibre, and with Cedar LNG which have all been approved and are moving forward, and that is a probably a simpler conversation than on the East Coast because of the proximity of the gas fields to where you would actually ship it from. You obviously have to do that in a manner that is consistent with Canada's climate plan so you have to reduce methane emissions in the upstream and you need to liquefy using clean electricity. On the East Coast, we certainly have had many conversations about this with premier Higgs and with others, about how could you get yourself into a position to export LNG from the east coast of Canada to Europe, which would include Greece obviously. Initially, the look was for the Repsol project and a couple of others bringing gas all the way from Alberta, and what we found and what Repsol found, is it did the economics, and I think Premier Higgs actually said this at committee today, was that that just wasn't economic. But certainly Premier Higgs, who has gas resource in New Brunswick, if he chose, chooses to develop them, could look to actually develop a project that could ship LNG to Europe, but obviously that would need to be done in a manner that's consistent with New Brunswick's climate plan."*

Kapelos *" Yeah on principle I guess I'm trying to figure out exactly where your government Falls, because there is a very live debate around whether or not, you know developing gas and exporting more of it helps get other places off more emissions intensive resource, or whether it adds overall to emissions because of the way in which it's developed and the fact that it is gas and not a renewable resource, and so I'm wondering like for example the US has decided to press pause on developing export capacity because of the potential climate impacts. Is that the posture of your government? Like are you gung-ho about gas or are you, you know, falling in line with the concern that adding more export capacity beyond what's on the table right now would negatively impact climate targets?"*

Wilkinson *"So, I mean, the pause in the US is actually so they can assess how it fits overall within the context of their commitments on climate. We actually did that years ago, so the Americans are actually following in Canada's footsteps, and what we have said is you have to do a lot to reduce emissions of methane in the upstream and we're bringing in place regulations to require 75% reductions. You have to actually liquefy using electricity, clean electricity, you can't just burn natural gas in order to liquefy or the carbon footprint that you leave is far too large. So we've already done that work, and what I would say is, as we move forward, there is a role for LNG in displacing heavier hydrocarbons like coal in some jurisdictions, but folks who are looking to make the investment, and this is the private sector that has to make this assessment, needs to also look at the timelines that are involved and how long it takes them to make back their money."*

Kapelos *"Your opponents have characterized your position on this as ideologically opposed to exporting a resource that we have. How do you respond to that characterization? Are you?"*

Wilkinson *"No, I would say we've actually got three projects that are actually moving forward in western Canada, we are working very closely with Premier Higgs on the Repsol project and the company came to the understanding that the project economics unfortunately just didn't work. But we also have a commitment to ensure that Canada is achieving its net zero goals and so it's got to be within that frame. We support the work that can be done to displace heavier hydrocarbons, but it's got to be within a frame that actually fits with respect to the commitments we and others have made."*

Kapelos “*Just one quick final question on what that support looks like. Will the government invest taxpayer dollars or subsidize the process of electrification for proponents that want your government to essentially fund that process?”*

Wilkinson “*So, we have said that the government is opposed to using government money to fund inefficient fossil fuel subsidies, we’re the first country in the world to actually do that. We’re not interested in investing in LNG facilities that’s the role of the private sector they need to assess the business case and make the investments.* “

Kapelos *“Okay minister, I’lll leave it on that note, thank you for your time as always.”*

The government is opposed to using government money to fund inefficient fossil fuel subsidies. We’re the first country in the world to actually do that. We are not interested in investing in LNG facilities. That's the role of the private sector. They need to assess the business case and make the investments,” said Wilkinson.

Prepared by SAF Group https://safgroup.ca/news-insights/

https://gasprices.aaa.com/dont-get-april-fooled-by-wobbling-gas-prices/

DON’T GET APRIL FOOLED BY WOBBLING GAS PRICES

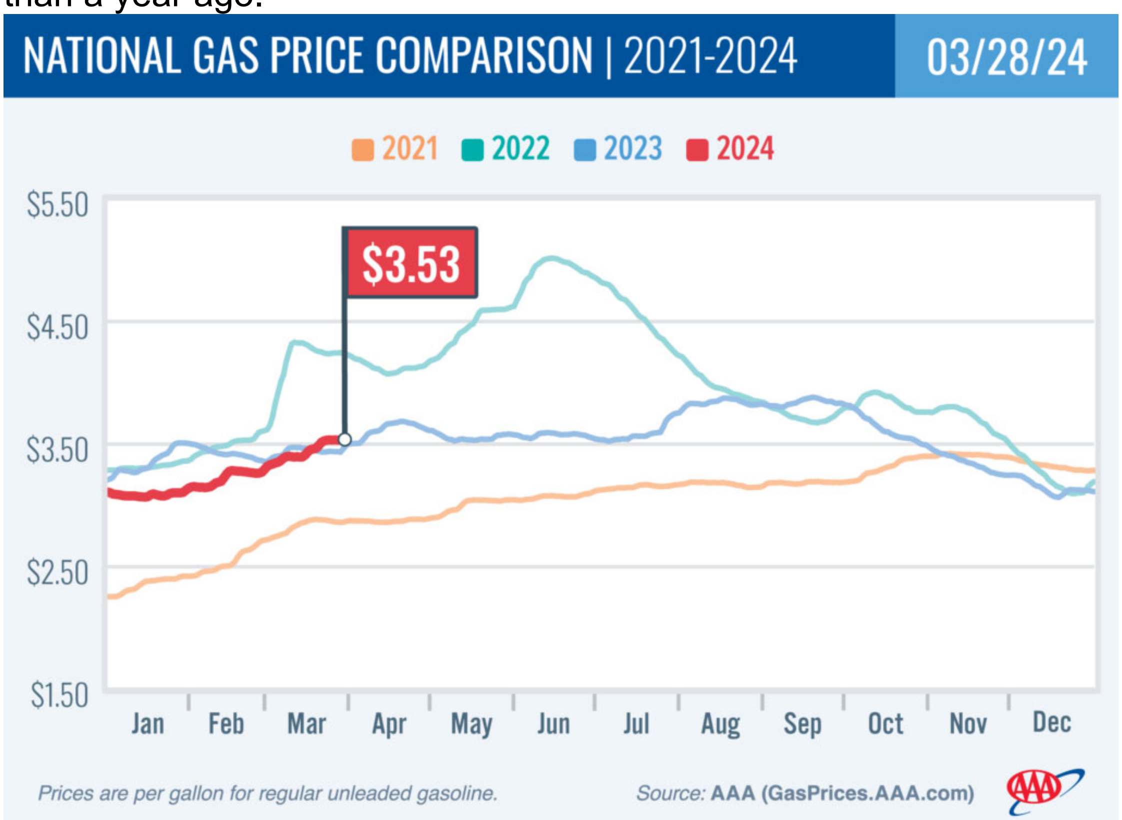
March 28,2024

WASHINGTON, D.C. — After an early spring surge, the national average for a gallon of gas spent the past week drifting up and down by a fraction of a cent before settling a penny higher at $3.53. But the break may be temporary, as gas pump prices will likely resume a spring increase.

“Uncertainty of the impact of Ukraine’s targeting of Russia’s oil infrastructure likely spiked oil prices recently,” said Andrew Gross, AAA spokesperson. “But those concerns have abated somewhat for now, and gas prices are settling into a pattern similar to last year when the usual seasonal increase was slow and steady.”

According to new data from the Energy Information Administration (EIA), gas demand dipped slightly from 8.81 to 8.72 million b/d last week. Meanwhile, total domestic gasoline stocks increased by 1.3 million bbl to 232.1 million bbl. Lower demand would typically contribute to pushing pump prices lower or slowing increases, but rising oil prices have kept them elevated instead.

Today’s national average of $3.53 is 24 cents more than a month ago and 10 cents more than a year ago.



Quick Stats

- Since last Thursday, these **10 states have seen the largest increases** in their averages: Utah (+26 cents), Idaho (+17 cents), Alaska (+15 cents), Nevada (+12 cents), Washington (+12 cents), Oregon (+11 cents), Wyoming (+7 cents), California (+7 cents), North Dakota (+6 cents) and Washington, DC (+6 cents).
- The nation's **top 10 most expensive markets**: California ($5.02), Hawaii ($4.69), Washington ($4.49), Nevada ($4.38), Oregon ($4.25), Alaska ($4.07), Illinois ($3.90), Arizona ($3.78), Utah ($3.76) and Washington, DC ($3.69).

Oil Market Dynamics

At the close of Wednesday's formal trading session, WTI decreased by 27 cents to settle at $81.35. Oil prices fell after the EIA reported that total domestic commercial crude stocks increased by 3.2 million bbl to 448.2 million bbl last week. Although stocks increased when compared to a year ago, the current stock level is 25.5 million bbl lower than at the end of March 2023.

Drivers can find current gas prices along their route using the AAA TripTik Travel planner.

https://www.convenience.org/Topics/Fuels/Changing-Seasons-Changing-Gas-Prices

Seasonal Gas Prices Explained

From refinery maintenance to consumer demand, seasonal fuel production affects gasolines prices at the dispenser.

February 28, 2024 3 min read

Traditionally, gasoline prices are at their lowest during the first week of February and then begin to climb, often peaking right before Memorial Day. Seasonal increases in demand plus a transition to unique fuel blends put pressure on gas prices each spring.

Since 2000, gasoline prices have increased about 50 cents from the seasonal low at the beginning of February to the seasonal high in mid-May. Here's a timeline of events that can affect gas prices during the first half of the year.

February: Refinery Maintenance

U.S. demand for gasoline is generally at its lowest during the first two months of the year, so refinery maintenance, known as a "turnaround," is often scheduled during the first quarter. A turnaround is a planned, periodic shut down (total or partial) of a refinery process unit or plant to perform maintenance, overhaul and repair operations and to inspect, test and replace materials and equipment.

Refineries undergo turnarounds roughly once every four year so about 25% of refineries undergo a turnaround each spring. Another reason for scheduling turnarounds is that they allow refineries to retool for summer-blend fuels.

March-April: Refineries Switch to Summer-Blend Production

The U.S. Environmental Protection Agency (EPA) defines April to June as the "transition season" for fuel production. Refineries lead this transition and switch over to summer-blend production in March and April.

Gasoline blends used in the summer months are different than the blends used in the winter. In the winter, fuels have a higher Reid vapor pressure, meaning they evaporate more easily and allow cars to start in colder weather. In the warm summer months, these evaporative attributes would lead to increased emissions and the formation of smog.

There are also more fuels to produce during the transition season. In the winter months, only a few fuels are used across the United States. However, because of various state or regional requirements, 14 different fuel specifications are required for the summer months. Refineries must produce enough fuel for each area to ensure there are no supply shortages, and that can complicate the production and distribution of fuels.

Summer-blend fuel is also more expensive to make than winter-blend fuel. First, the production process takes longer and, second, the overall yield of gasoline per barrel of oil is lower. These complexities add as much as 15 cents per gallon to the cost to produce these higher-grade fuels.

May-June: Deadlines for Terminals and Retailers

The May 1 compliance deadline for terminals to fully purge their systems of winter-blend fuels is considered one of the biggest factors in seasonal price increases. This regulatory requirement can lead to lower inventories at the terminal, which also puts upward pressure on gas prices. It can also take fuels refined in the Gulf Coast several weeks to reach storage terminals throughout the country, which is why it's important to have summer-blend fuel at terminals and storage facilities by May 1. This date is the most important reason that seasonal gas prices tend to peak in May.

In most areas of the country that require summer-blend fuels, retailers have until June 1 to switch to summer-grade gas.

February-August: Summer Drive Season and Increased Demand

Demand can play a role in elevating seasonal gas prices. Gas demand increases a few percentage points each month beginning in February and peaks in August. Total fuel demand is 10% to 15% greater in August than in February, and any stress to the system—such as a refinery or pipeline outage—can cause a supply/demand imbalance and affect prices.

September: A Welcome Change

As gasoline demand decreases and temperatures cool, retailers are able to switch to selling winter-blend fuel beginning September 15. While these winter-blend fuels are cheaper to produce, the complications of the switchover can result in a temporary bump in price. Weather conditions, such as hurricanes, can also affect gas prices in the late summer to fall months.

Unlike in the spring, the change to winter-blend fuel is not required. However, because winter-blend fuel costs less, retailers often sell the fuel blend to remain price competitive. Not all retailers begin selling this fuel on September 15; many make the switch when their inventories are low.

By the end of September, gas prices generally decrease as the switchover processes and demand continues to fall. And despite conspiracy theories, lower gas prices do not correlate to pre-election politics.

In California, the season for summer-blend fuels is longer than the rest of the country. Both Northern and Southern California's summer-blend requirements run through the end of October. This exacerbated supply issues within the state in early October 2012, when fires at two large refineries limited state-specific production and caused wholesale and retail gas prices to spike to record levels.

Meanwhile, demand for distillate fuel (diesel fuel and home heating oil) begins to increase in September because of both greater diesel fuel demand related to the harvest and greater home heating oil demand because of the colder weather.

Exceptions to the Rule

Summer-blend fuel requirements may be relaxed in times of emergencies or when potential shortages are possible.

In 2005, NACS worked with Congress to give the EPA the authority to waive certain regulations affecting the motor fuels system in times of emergency. The EPA's immediate use of these waivers is critical to bringing the entire fuel supply chain into operation as quickly and safely as possible. For example, this flexibility allowed winter blends of gasoline to enter into the market in 2017 before the traditional transition date of September 15 in response to Hurricanes Harvey, Irma and Maria.

https://www.transmountain.com/news/2024/update-april-2024-capacity-announcement-for-the-trans-mountain-pipeline-system

Update: April 2024 Capacity Announcement for the Trans Mountain Pipeline System

Apr. 1, 2024

Total system nominations for the Trans Mountain Pipeline system are apportioned by 24 percent for April 2024. The pipeline will be running full at its maximum capacity.

What is pipeline 'apportionment' and why is it important?

The energy sector around the world works on a monthly cycle. The Trans Mountain Pipeline is part of that cycle. Apportionment describes the amount of demand shippers place on the pipeline in excess of its available capacity. Here's a step-by-step guide to the apportionment determination that's carried out every month for the existing Trans Mountain Pipeline system.

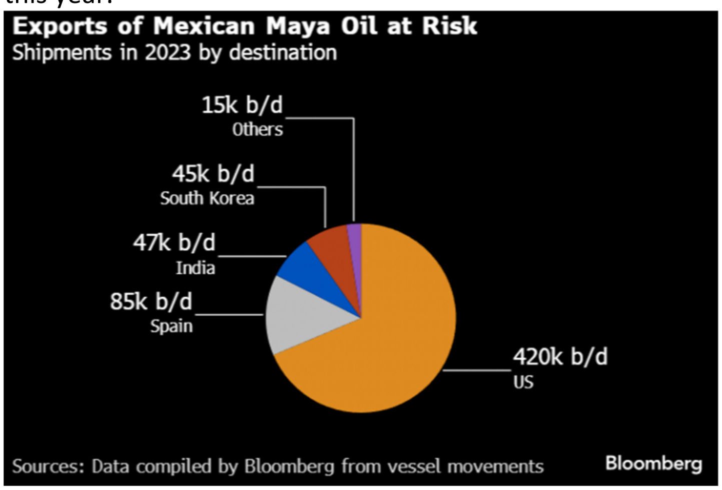
- Each month our shippers submit requests for how much petroleum (crude oil and refined products) they want to ship through the pipeline to service their customers. These requests are called 'nominations'.
- Based on shippers' nominations, we then determine the 'capacity' available on the pipeline for the month. Determining pipeline capacity is complex. Capacity is affected by, among other things, the types of products that have been nominated, any pipeline system maintenance activities that will reduce flows that month and carry-over volumes that haven't completed their transit of the pipeline by month's end.
- Based on available pipeline capacity and the volume of shipper nominations we received, we calculate apportionment using a method accepted by the Canada Energy Regulator and forming part of our tariff. A tariff includes the terms and conditions under which the service of a pipeline is offered or provided, including the tolls, the rules and regulations, and the practices relating to specific services.
- If shipper nominations are less than pipeline capacity, the apportionment percentage to that destination is "zero" and all the product volumes nominated by shippers are accepted to be transported that month.
- If shipper nominations exceed pipeline capacity, the apportionment is a percentage greater than zero.

Mexico to Halt Some Oil Exports, Further Squeezing Global Market
2024-04-01 18:16:54.646 GMT
By Lucia Kassai

(Bloomberg) -- Mexico's state-controlled oil company plans to halt some crude exports over the next few months, a move that would cut supply from a tightening global market.

Petroleos Mexicanos, also called Pemex, canceled contracts to supply its flagship Maya crude oil to refiners in the US, Europe and Asia, according to people with knowledge of the situation, who asked not to be named because the information is private.

The export cut, coming at a time when OPEC and its allies are already curbing production, threatens to drive up oil prices that are at a six-month high. Physical supplies — especially heavier, sour grades such as Maya — are tightening even further with Venezuelan exports set to fall after the reinstatement of US sanctions on its oil industry. JPMorgan Chase & Co. last week warned that global benchmark Brent could reach $100 a barrel this year.



Pemex's plan to suspend some exports is part of an effort to produce more domestic gasoline and diesel ahead of the June 2 presidential election, the people said. President Andres Manuel Lopez Obrador, whose term is coming to an end, won office with the promise of weaning the country off of costly fuel imports. His multi-year effort to revamp Mexico's refining sector is finally paying off.

In February the country's six refineries operated near the highest rates seen in more than six years. Oil use should keep rising as Pemex works to start commercial operations of the new Olmeca refinery, also known as Dos Bocas, with capacity to process 340,000 barrels of crude oil a day.

Pemex didn't immediately return call and messages seeking comment.

The halt affects primarily exports of Maya while shipments of other grades including medium sour Isthmus should continue at reduced volumes, the people said. It's unclear if Pemex's trading arm PMI will be able to follow through on the export cut. In 2021 and later in 2023 the company had to shelve plans to halt oil exports after it failed to increase domestic fuelmaking.

US refiners are likely to bear the brunt of the cut in Maya exports. Fuelmakers including Valero Energy Corp, Chevron Corp and Marathon Petroleum Corp import 420,000 barrels of the heavy sour variety per day. In 2023, Maya exports reached 612,000 barrels a day.

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https://www.wsj.com/world/americas/biden-is-unlikely-to-reimpose-oil-sanctions-on-venezuela-9fc8ac7c

1. EXCLUSIVE
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Biden Is Unlikely to Reimpose Oil Sanctions on Venezuela

Nicolás Maduro of Venezuela has barred presidential candidates, but U.S. officials worry that new penalties would raise gas prices in a U.S. election year

By Kejal Vyas Follow , Patricia Garip and Juan Forero Follow

March 29, 2024 4:09 pm ET

The Biden administration is leaning away from reimposing sanctions on Venezuela's oil industry despite President Nicolás Maduro's moves to bar leading opposition candidates from the country's July elections, said people familiar with the matter.

U.S. officials are concerned that reverting to Trump-era sanctions that accelerated the decline of Venezuela's oil production would raise the price of gas at U.S. pumps and prompt more migration from Venezuela as President Biden campaigns for re-election in November. Restricting Western oil companies would tighten global energy supplies and open the way for Chinese investment in Venezuela, they say.

Biden administration officials have said they didn't think that the oil sanctions—leveled against Venezuela in early 2019 in former President Donald Trump's effort to force Maduro from power—was constructive.

Top officials including national security adviser Jake Sullivan; Amos Hochstein, senior White House energy adviser; and Deputy national security adviser Jon Finer are encouraging a different approach that emphasizes broader strategic interests such as energy supply over political change in Caracas.

"We are committed to maintain sanctions relief if Maduro and his representatives uphold the commitments outlined" in a deal they signed in October for an electoral road map, a senior U.S. administration official said Friday. "We urge Maduro to do so."

Maintaining the current policy "spells a greater opportunity of keeping Venezuela as part of the Western marketplace, less inclined to spin back in the direction of China and Iran," said an oil industry adviser familiar with the deliberations.

In October 2023, after secret talks between U.S. and Venezuelan officials in Qatar, the Biden administration issued a six-month general license, which expires April 18, allowing oil companies to work in Venezuela. The license expanded an easing of sanctions that since late 2022 had been mostly limited to Chevron, the largest private company with assets in Venezuela. In exchange, Maduro's regime pledged to work toward free and fair elections this year and agreed to receive Venezuelan deportees as the U.S. grapples with record migration.

Instead, the government halted the short-lived deportation deal, arrested a range of political opponents and banned from office Maria Corina Machado, an opposition politician who had been chosen in a primary to challenge him.

When Machado and opposition political parties last week named an 80-year-old grandmother and academic as a replacement candidate, the government banned her, too. A poll by the American company ClearPath Strategies showed Machado or any candidate she backed would easily defeat Maduro in a vote.

"I said at the time, you lift the sanctions now, you take away your own leverage," said Eric Farnsworth, a former high-ranking State Department diplomat who is vice president of the Council of the Americas policy group in Washington. "That is exactly what happened."

The Biden administration is likely to extend the current policy until July 28, when Venezuela will hold elections, people familiar with the administration's thinking say, allowing oil companies and traders to engage with national oil company Petróleos de Venezuela for now. U.S. oil executives are negotiating deals in Caracas in the hopes of a more enduring commercial opening.

Those familiar with the administration's thinking don't rule out some punitive measures, such as restricting payment for Venezuelan oil to local currency rather than U.S. dollars.

"Fundamentally, the maximum pressure strategy was something that did not lead to the outcome it intended to promote regime change through crushing sanctions," Juan Gonzalez, who until recently was the White House's top Latin American adviser, told reporters in February.

The Biden administration has quietly retained Gonzalez as a go-between with Venezuela in ongoing talks, the people familiar with the matter said. A face-to-face meeting is scheduled for early April, possibly in Doha or Mexico City.

Among the U.S.'s top concerns regarding Venezuela has been the exodus of migrants, hundreds of thousands of whom have sought asylum after crossing the American southwestern border. Sanctions relief helped Venezuela raise daily oil production by nearly 200,000 barrels in three years, to about 800,000.

For some analysts who track U.S. policy in Latin America, the Biden administration's opening to Maduro failed.

"After all that's been done, without snapping back sanctions, we lose credibility," said Ryan Berg, who tracks Venezuela at the Center for Strategic and International Studies in Washington. "If we don't have accountability, I think Maduro would be laughing at us."

Geoff Ramsey, Venezuela director at the Atlantic Council in Washington, said a policy that gives priority to Western energy interests would require "significant concessions" from Maduro.

"I don't see the administration completely scrapping a democracy and human rights agenda," he said. "The White House has walked a fine line between pursuing U.S. energy and geopolitical interests while also trying to encourage a gradual democratic opening in Caracas."

In Latin America, Maduro's measures sparked criticism.

Argentine President Javier Milei's government issued a statement calling on Maduro to "ensure the safety and welfare of the Venezuelan people as well as convening transparent elections." In

Brazil, President Luiz Inácio Lula da Silva and French President Emmanuel Macron called the exclusion of the Venezuelan candidate, Corina Yoris, “serious.”

“I just want the elections carried out the way they are in Brazil, whoever wants to take part, takes part,” said da Silva.

In Caracas, foreign energy executives say they have taken comfort in the U.S.’s unwillingness to sever business ties with Venezuela, despite the rocky political climate.

Chevron, which was given a special license by the U.S. Treasury in 2022 to operate in Venezuela, plans to drill dozens of wells this year in a bid to raise its output to 200,000 barrels a day, roughly a quarter of the country’s total production. Italy’s Eni and Spain’s Repsol have also been operating under special exemptions that the U.S. made to its sanctions policy. Other oil companies are in talks with the U.S. over securing terms similar to Chevron’s.

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Guyana condemns Venezuela for signing into law a referendum approving annexation of disputed region
2024-04-04 17:08:22.697 GMT

Guyana condemns Venezuela for signing into law a referendum approving annexation of disputed region

By BERT WILKINSON

GEORGETOWN, Guyana (AP) — Venezuelan President Nicolás Maduro's move to sign into law the results of a recent referendum laying claim to two-thirds of Guyana triggered fierce condemnation Thursday from the neighboring South American country's government.

The text of the law was not immediately made public. Even so, Guyana's Ministry of Foreign Affairs vowed not to yield any land to Venezuela and called the move targeting Guyana's western Essequibo region an "egregious violation of the most fundamental principles of international law."

In early December, Maduro held a referendum to claim sovereignty over the oil- and mineral-rich region that represents two-thirds of Guyana, arguing it was stolen when the border was drawn more than a century ago. On Wednesday, Maduro held a signing ceremony recalling the referendum as a "stellar and historic moment."

"The decision of December 3, has now become the Law of the Republic, to form part of the legal structure of the internal political and institutional movement of our country," Maduro tweeted on Wednesday. "The decision made by the Venezuelans in the consultative referendum will be fulfilled in all its parts, and with this Law, we will continue the defense of Venezuela on international stages."

Guyana's government responded sharply hours later: "If Venezuela wants to contest title to the territory in question, the proper forum is the International Court of Justice."

It's not clear how Venezuelan authorities intend to implement the idea of exercising jurisdiction over Essequibo. Maduro said that until the dispute is resolved, the appointment of an Essequibo governor will remain in his hands and that the National Assembly will exercise legislative powers of the territory. He did not provide further details.

Guyana and Venezuela have been feuding over the region for decades, with tensions deepening after vast oil deposits were found near Guyana's coast in 2015 in offshore areas intersecting the disputed territory.

In 2018, Guyana took the case to the United Nations' highest court, asking judges to rule that an 1899 border decision is valid and binding. Meanwhile, Venezuela insists that a 1966 agreement nullified the original arbitration.

A court ruling is not expected before next year.

Meanwhile, Guyana is collaborating with the U.S., France and India to fortify its military in the event of any annexation attempts, President Irfaan Ali said recently. Guyana’s military also has stepped up recruitment exercises with advertisements on social media sites and visits to various regions around the country.

Satellite imagery has revealed that Venezuela’s military is amassing troops and expanding bases near the border it shares with Guyana.

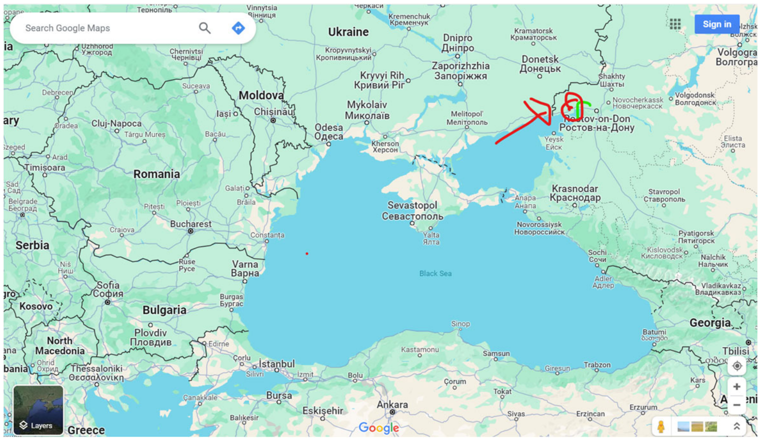
The presidents of Guyana and Venezuela met in the eastern Caribbean island of St. Vincent in mid-December at the urging of regional leaders who have tried to diffuse the situation, but they failed to resolve the territorial dispute, agreeing only to not use threats or force against each other.

A second meeting between Ali and Maduro was supposed to been held last month, but not date has been scheduled.

[Editor notes: Eds: UPDATES: Updates Media.]

-0- Apr/04/2024 17:08 GMT

To view this story in Bloomberg click here:
https://blinks.bloomberg.com/news/stories/SBFGXYTVI5MO



Source: GoogleMaps

https://en.interfax.com.ua/news/general/978536.html

12:34 06.04.2024

Pipeline for pumping petroleum products blown up in Rostov region in Russia – Defense Intelligence

1 min read

In Rostov region of the Russian Federation, a pipeline used to pump petroleum products from a local oil depot to tankers in the area of the Azov Sea Port was blown up, the Defense Intelligence of the Ministry of Defense of Ukraine reported on Telegram.

“On the night of April 6, 2024, in the area of the village of Azov (Rostov region) as a result of the explosion of a pipeline that pumped petroleum products from a local oil depot to tankers in the area of the Azov Sea Port, the loading of tankers with petroleum products was suspended for an indefinite period,” the report says.

“The object was used by the aggressor state for military purposes, to support the waging of a genocidal war against Ukraine,” the department noted.

GLOBAL COMMODITY STRATEGY AND MENA | RESEARCH

Geopolitical Update: Temperatures Rising

Analysis and Updates on Conflicts in Ukraine and the Middle East

March 27, 2024

RBC Capital Markets, LLC
Helima Croft (Head of Global Commodity Strategy and MENA Research) (212) 618-7798; helima.croft@rbccm.com

President Biden faces the prospect of a cruel summer if the Russia-Ukraine and Middle East conflicts continue to pose risks to global energy supplies.

- **This week brought more attacks by Ukraine on Russian refineries with drones circling back to two previously targeted refineries, Novokuibyshevsky and Kuibyshevsky, in the Samara region, resulting in significant damage to the latter's primary crude distillation unit.** As a result, we now count 5 refineries facing significant throughput disruptions, with our estimates for downed refining capacity rising to 13% of Russia's total. These attacks seem to be serving the twin purposes of partially denying the Russian frontlines diesel as well as reducing Russia's essential energy revenue to fund the war. Preliminary estimates already show aggregate Russian refinery runs in March down 650 kb/d y/y. While it is still too early to see how these disruptions will ultimately affect seaborne refined product export flows, the largest impacts would be seen on global gasoil and fuel oil markets. Turkey, Africa, and Brazil have been the top destinations for Russian gasoil since exports were barred from Europe.
- **There have been reports that the White House has tried to dissuade Kyiv from this strategy, fearing the energy price impact – we find this entirely credible based on our conversations.** As we have repeatedly noted, the White House has sought to avert a Russian supply disruption and has shaped policy towards this end; including price caps designed as a release valve to ensure Russian barrels locked out of Europe would flow to Asia, or directly telling Ukraine to not target Black Sea oil tankers. However, with US assistance being held up in Congress, and Russia making battlefield gains, Ukraine and key regional allies appear to be questioning the utility of this energy bargain with Washington.
- **A key dynamic worth watching is whether Congress moves to approve the $60bln supplementary military, budgetary, and humanitarian aid package being held up in the House after already passing in the Senate.** House Speaker Mike Johnson (R-LA) has signaled a willingness to hold a vote on Ukraine support after Congress's Easter recess, however at the time of writing, there are no clear indications of imminent passage. Moreover, with a complete cutoff of funding potentially in the offing if President Trump wins in November, the window for Ukraine to make battlefield advances in the two-year conflict may be closing.

- **Hence, we will be closely watching whether Ukraine moves at some stage to target actual export facilities to strike a deeper blow on the Russian balance sheet.** We continue to contend that Ukraine seemingly has the capability to target the majority of export facilities in western Russia, which would put ~60% of Russia's crude exports at risk. While Washington would certainly not be happy with such a move because of the serious price implications, Kyiv could decide that such asymmetrical measures may be necessary. Resilient energy revenue has been essential for Russia's continued military strength – the 2024 budget contains record defense spending, with the Russian Federation for the time poised to spend over 6% of GDP on military and defense spending. At the same time, Moscow is forecasting a shrinking deficit based on an anticipated rise in revenue this year. According to the Carnegie Endowment, the 2024 budget is based on the assumption that revenue will climb by over a third to over ₽35tln ($378bln), of which ₽11.5tln ($124bln) is expected to come from the oil and gas sector.
- **While OPEC is sitting on over 2 mb/d of spare capacity, we do not think the producer group would rush in to cool the rally and ramp up output given what transpired in the months immediately following the Russian invasion of Ukraine.** Washington made unprecedented interventions in the market by releasing 180 mb from the SPR after the IEA and other market participants warned of a multimillion b/d Russian disruption that never materialized. Certainly, we do not see any indications that the recent run up in prices due to the heightened Russian infrastructure risk will prompt any policy reversal at next week's Joint Ministerial Monitoring Committee Meeting. Any serious shift will likely have to wait until the June 1 Ministerial Meeting, and even then, we believe the group will be very judicious when it comes to unwinding any cuts.
- **Complicating the challenge for the White House is the lack of progress in resolving the six-month Middle East war.** The Houthis continue to attack ships in the Red Sea, claiming six attacks on Tuesday, while Houthi officials this week have renewed threats against Saudi Arabia over providing support and airspace access to US jets conducting strikes in Yemen. In addition, the continuing exchange of fire between Hezbollah and Israel – with Hezbollah launching "dozens" of rockets in response to deadly Israeli strikes in southern Lebanon yesterday – still represents a serious contagion risk.
- **Hence, it is our view that Washington may once again have to resort to policy tools such as the SPR if these twin conflicts continue to imperil global energy supplies. Certainly, this raises a campaign risk for President Biden, as his opponents will likely accuse him of endangering energy security by tapping further into the strategic reserve. However, if President Biden cannot find a way to ameliorate the risk from these conflicts, the White House may decide that SPR releases are more politically palatable than retail gasoline prices north of $4/gallon for the summer driving season.**

Continue Reading

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04/02/2024 06:46:30 [BN] Bloomberg News

Russian Crude Processing Picks Up After Drone Strikes Cut Output

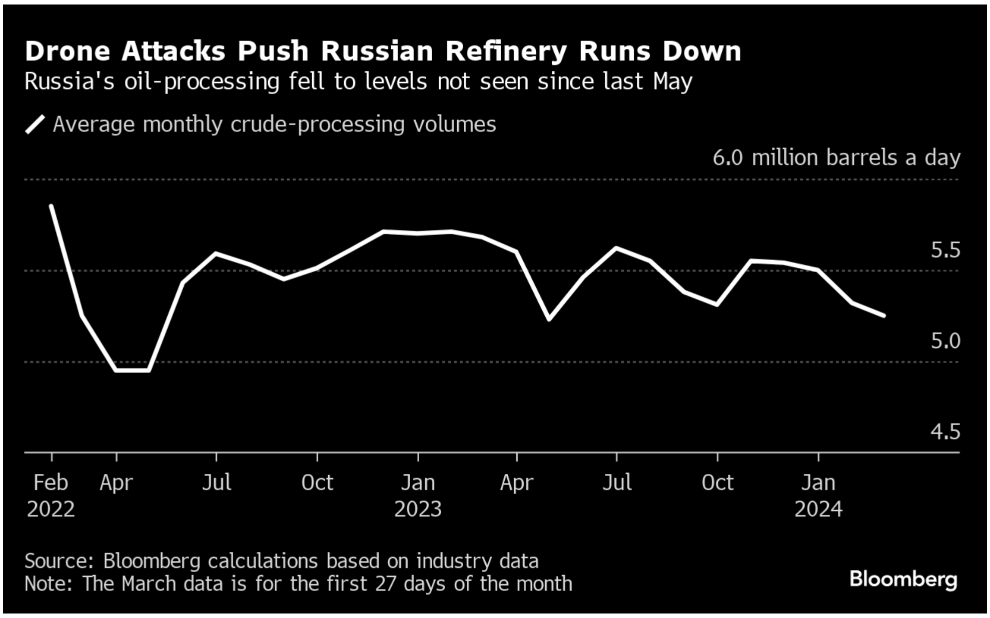
- Refineries handled 5.13 million barrels a day from March 21-27
- Latest drone attack targets plant in Tatarstan early Tuesday

By Bloomberg News

(Bloomberg) -- Russia's weekly crude processing picked up in late March after sinking to a 10-month low earlier in the month.

The nation's refineries churned through an average of 5.13 million barrels a day March 21-27, according to a person with knowledge of industry data. That's almost 106,000 barrels a day more than they processed the previous seven days, according to Bloomberg calculations based on historical data.

But the month as a whole saw rates dip. In the first 27 days of March, refinery runs averaged 5.25 million barrels a day, 1.3% below the level through most of February and the lowest monthly rate since May, the data show.



With the invasion of Ukraine in its third year, Kyiv has been using drones to target Russia's most important industry. The government has defended the strategy, saying it's seeking to curb fuel supplies to the front line and cut the flow of petrodollars to Kremlin coffers, but US officials have reportedly warned that the attacks risk driving up global oil prices.

Ukrainian drones have damaged 12 major Russian refineries and two smaller plants so far this year, with the latest attack occurring Tuesday at a facility in Nizhnekamsk, about 930 miles from the countries' border. The total capacity of those sites accounted for more than 30% of Russia's runs before the assaults started, according to Bloomberg calculations based on industry data.

The actual reduction in crude processing is visibly smaller because most of the affected sites have been able to repair damaged equipment, partly or completely restoring capacity by the end of March. Some other plants have also increased throughput to ensure fuel demand is met.

Risks to Runs

Ukrainian President Volodymyr Zelenskiy's insistence that strikes will continue means the recovery in refinery runs may prove short-lived. Processing is also likely to decline once the spring maintenance season gets underway.

The recent uptick in runs was largely led by smaller independent facilities, according to the person familiar. But oil giant Rosneft PJSC also contributed to the growth, with its Ryazan plant near Moscow — hit by drones March 13 — raising processing by almost 85,000 barrels a day week-on-week, the person said.

Two more Rosneft refineries damaged in recent drone assaults — Kuibyshev and Syzran in the Volga region — showed further declines in output, while the southern Tuapse plant, attacked in January, remained offline, the person said.

Gazprom Neft PJSC's Moscow refinery, which started seasonal maintenance in late March, continued to show lower processing rates, the person said.

Rosneft and Gazprom Neft didn't immediately respond to Bloomberg requests for comment.

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04/02/2024 07:36:44 [BN] Bloomberg News

Russia's Seaborne Crude Exports Surge to the Highest This Year

Overall first-quarter exports were in line with Moscow's OPEC+ pledge

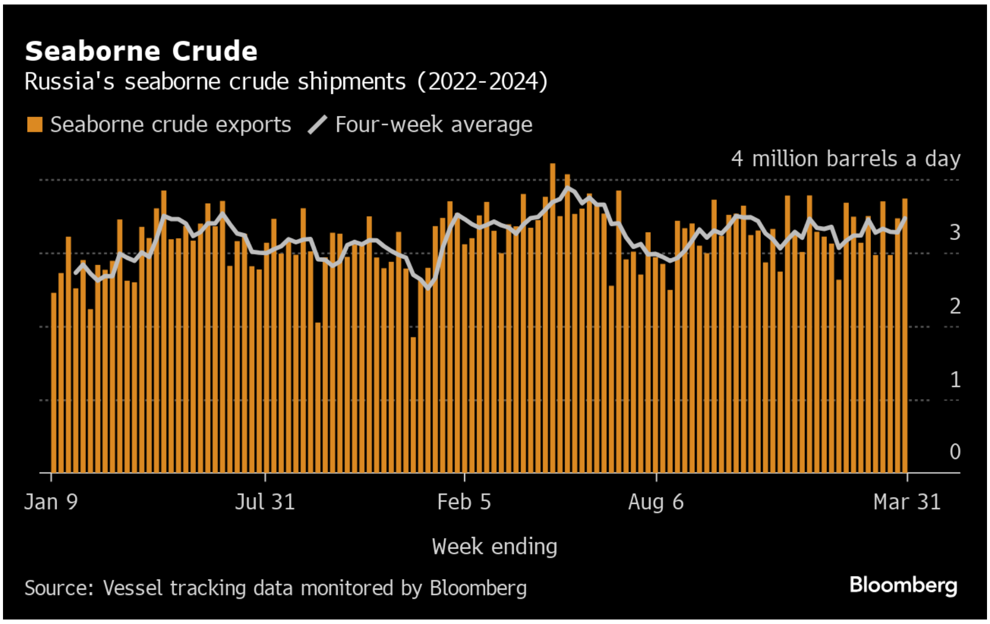
By Julian Lee

(Bloomberg) -- Russia's seaborne crude exports jumped in the final week of March to the highest so far this year, even as average shipments in the first quarter were close to the level pledged by Russia to its OPEC+ partners.

Last week's rebound came amid an easing of the high winds that repeatedly hampered loadings at Russia's main Pacific port in recent weeks. While those earlier storms are still affecting four-week average flows, their impact is lessening. The less-volatile measure of shipments reached its highest since early November in the period to March 31, tanker-tracking data compiled by Bloomberg show.

Russia said it would cut crude exports during the first quarter of 2024 by 300,000 barrels a day from their average May-June level as part of a wider OPEC+ initiative to avert a surplus and support oil prices. Seaborne shipments in the first three months of the year exceeded that level by just 16,000 barrels a day. Over the course of the second quarter, Moscow will move away from cutting exports to focus on production targets, which are preferred by other members of the group.

The surge in shipments helped boost Moscow's oil earnings, despite a program of sanctions designed to squeeze the Kremlin's ability to fund its war in Ukraine. The gross value of crude exports soared to a five-month high of $1.9 billion in the seven days to March 31 from a revised $1.75 billion in the period to March 24. Four-week average income was also up, rising by about $110 million to $1.74 billion a week.



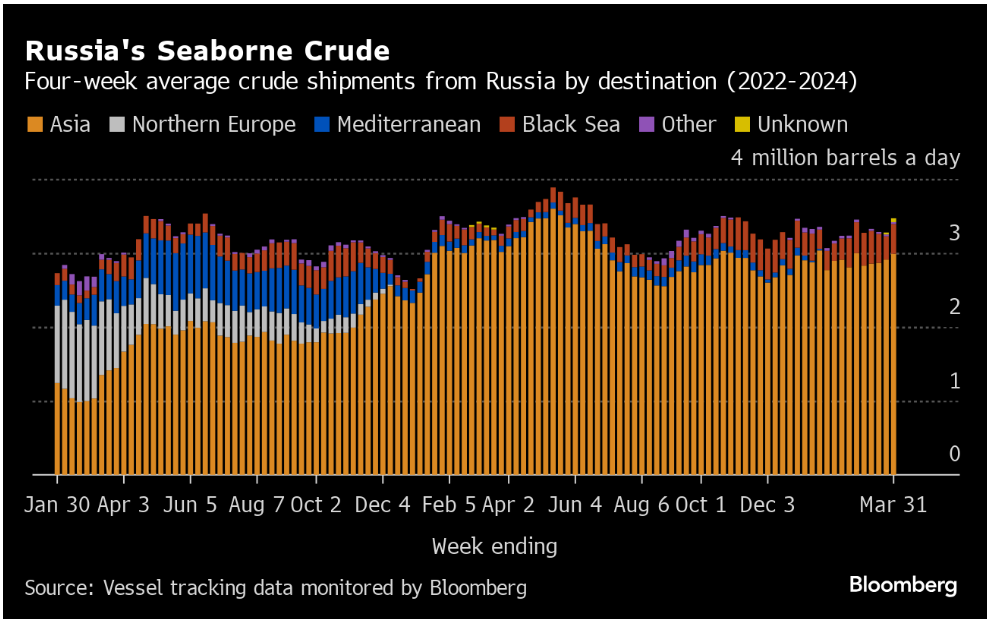
Most of the backlog of Russia's Sokol crude that built up after being turned away by Indian refiners has now been discharged. About 9.1 million barrels, half of the total, have been delivered to refineries in China. Another 7 million barrels are finding their way back to India – though almost half of that is still on tankers anchored at Indian ports. One cargo was delivered to Pakistan.

That leaves just 1.4 million barrels still to show a destination. All of the Sokol cargoes loaded in March headed directly to China.

Flows by Destination

Russia's seaborne crude flows in the week to March 31 rose 270,000 barrels a day to 3.74 million, its highest level for the year so far. The less volatile four-week average also increased, up by about 190,000 barrels a day to 3.47 million to the most since November.

Weekly shipments were about 150,000 barrels a day higher than the average seen in May and June, or about 450,000 barrels a day above Russia's first quarter target that is part of the OPEC+ alliance's broader effort to curb supplies and support prices. The four-week average was about 185,000 barrels a day above the target.



All figures exclude cargoes identified as Kazakhstan's KEBCO grade. Those are shipments made by KazTransoil JSC that transit Russia for export through the Black Sea port of Novorossiysk and the Baltic's Ust-Luga and are not subject to European Union sanctions or a price cap.

The Kazakh barrels are blended with crude of Russian origin to create a uniform export grade. Since Russia's invasion of Ukraine, Kazakhstan has rebranded its cargoes to distinguish them from those shipped by Russian companies.

- **Asia**

Observed shipments to Russia's Asian customers, including those showing no final destination, edged higher to 3.04 million barrels a day in the four weeks to March 31, up from a revised 2.94 million in the previous four-week period. That's the most since July.

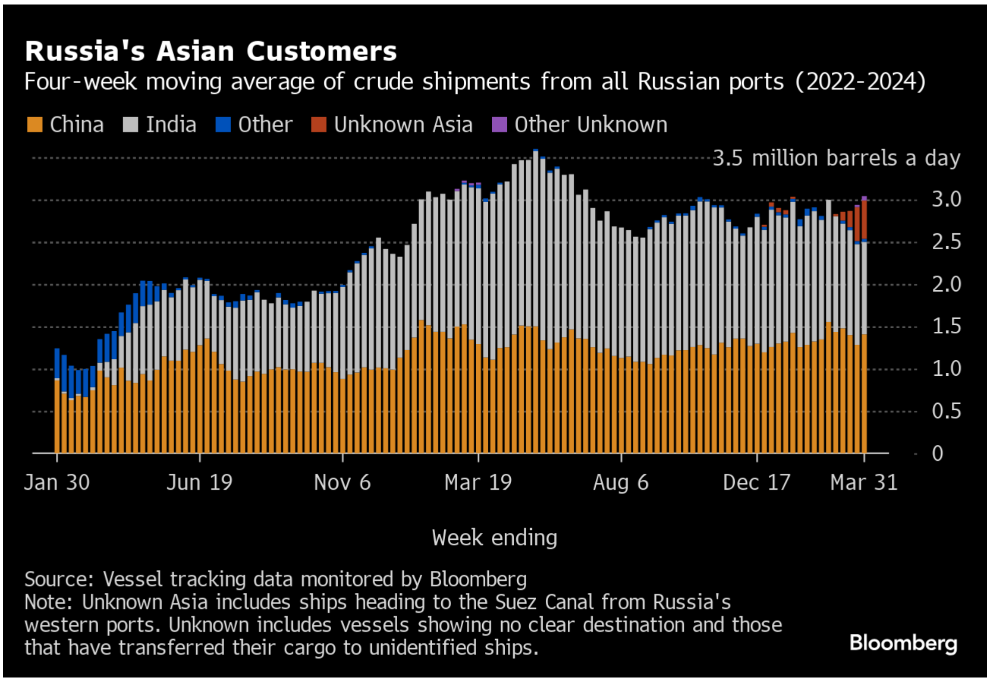
About 1.41 million barrels a day of crude was loaded onto tankers heading to China. The Asian nation's seaborne imports are boosted by about 800,000 barrels a day of crude delivered from Russia by pipeline, either directly, or via Kazakhstan.

Flows on ships signaling destinations in India averaged about 1.09 million barrels a day.

Both the Chinese and Indian figures will rise as the discharge ports become clear for vessels that are not currently showing final destinations.

The equivalent of about 455,000 barrels a day was on vessels signaling Port Said or Suez in Egypt, or are expected to be transferred from one ship to another off the South Korean port of Yeosu. Those voyages typically end at ports in India or China and show up in the chart below as "Unknown Asia" until a final destination becomes apparent. This figure includes stranded Sokol crude cargoes that are still waiting to discharge after failing to find homes in India since mid-December.

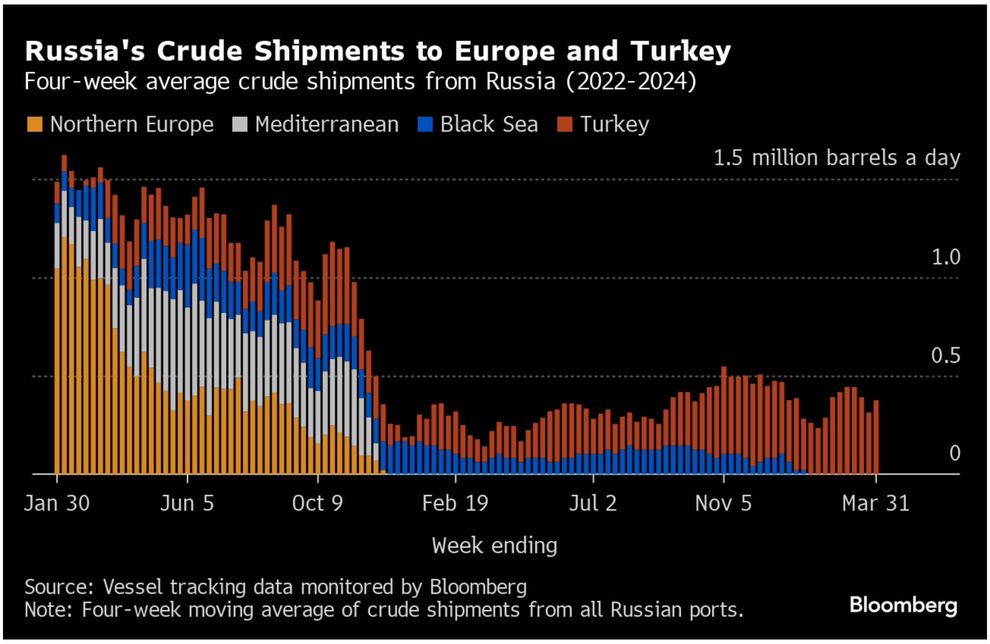
The "Other Unknown" volumes, running at about 50,000 barrels a day in the four weeks to March 31, are those on tankers showing no clear destination. Most of those cargoes originate from Russia's western ports and go on to transit the Suez Canal, but some could end up in Turkey. Others could be moved from one vessel to another, with most such transfers now taking place in the Mediterranean, off the coast of Greece.



Europe and Turkey

Russia's seaborne crude exports to European countries have ceased.

With flows to Bulgaria halted at the end of last year, Turkey is now the only short–haul market for shipments from Russia's western ports.



Exports to Turkey rebounded to about 375,000 barrels a day in the four weeks to March 31 from a revised 313,000 barrels a day in the period to March 24.

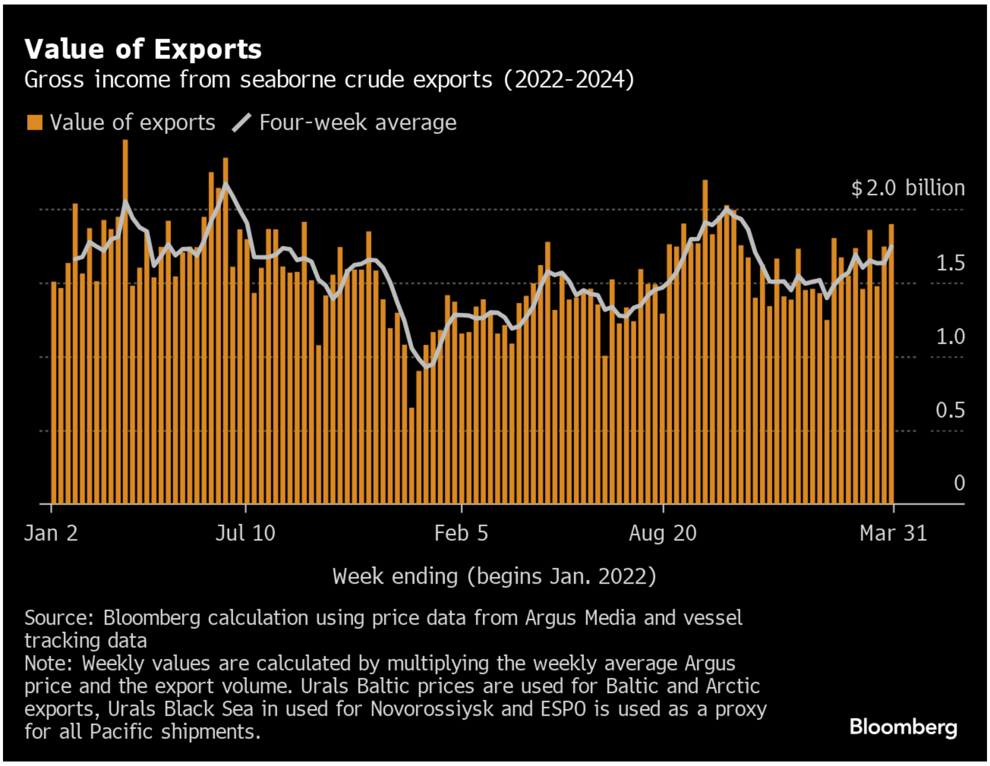
Vessel–tracking data are cross–checked against port agent reports as well as flows and ship movements reported by other information providers including Kpler and Vortexa Ltd.

Export Value

Following the abolition of export duty on Russian crude, we have begun to track the gross value of seaborne crude exports, using Argus Media price data and our own tanker tracking.

The gross value of Russia's crude exports soared to a five–month high, rising to $1.9 billion in the seven days to March 31 from a revised $1.75 billion in the period to March 24. Four–week average income was also up, rising by about $110 million to $1.74 billion a week. The four–week average is still well off its peak of $2.17 billion a week, reached in the period to June 19, 2022. The highest it reached last year was $2 billion a week in the period to Oct. 22.

During the first four weeks after the Group of Seven nations' price cap on Russian crude exports came into effect in early December 2022, the value of seaborne flows fell to a low of $930 million a week, but soon recovered.



The chart above shows a gross value of Russia's seaborne oil exports on a weekly and four-week average basis. The value is calculated by multiplying the average weekly crude price from Argus Media Group by the weekly export flow from each port. For shipments from the Baltic and Arctic ports we use the Urals FOB Primorsk dated, London close, midpoint price. For shipments from the Black Sea we use the Urals Med Aframax FOB Novorossiysk dated, London close, midpoint price. For Pacific shipments we use the ESPO blend FOB Kozmino prompt, Singapore close, midpoint price.

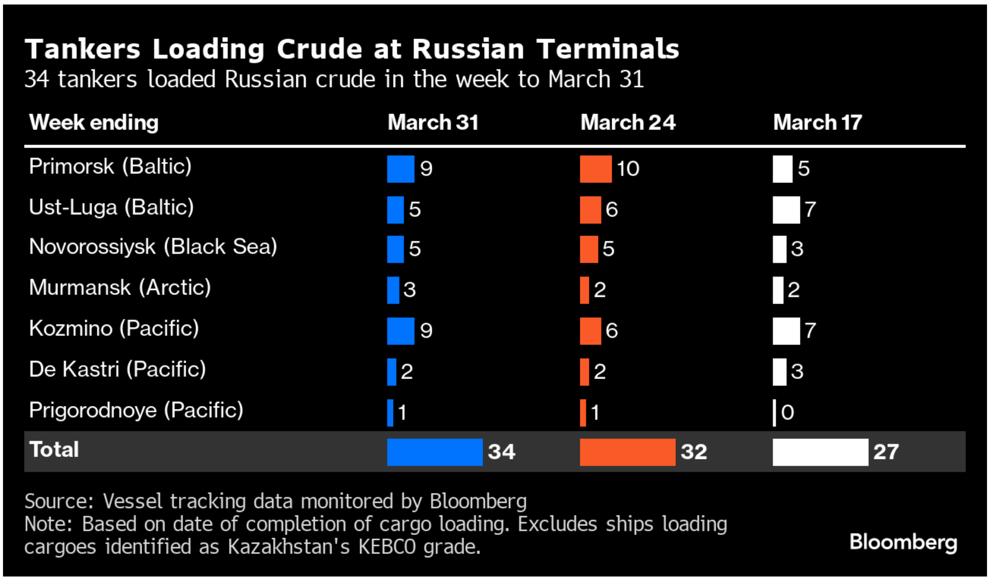
Export duty was abolished at the end of 2023 as part of Russia's long-running tax reform plans.

Ships Leaving Russian Ports

The following table shows the number of ships leaving each export terminal.

A total of 34 tankers loaded 26.2 million barrels of Russian crude in the week to March 31, vessel-tracking data and port agent reports show. That was up by about 1.9 million barrels from the revised figure for the previous week.

Shipments from Russia's Pacific terminal at Kozmino returned to a more normal level after flows the previous week were hampered by winds that were gusting above 30 miles per hour, according to data from visualcrossing.com.



All figures exclude cargoes identified as Kazakhstan's KEBCO grade. One cargo of KEBCO was loaded at Novorossiysk and one at Ust-Luga during the week.

NOTES

Note: This story forms part of a weekly series tracking shipments of crude from Russian export terminals and the gross value of those flows. Weeks run from Monday to Sunday. The next update will be on Tuesday, April 9.

Note: All figures exclude cargoes owned by Kazakhstan's KazTransOil JSC, which transit Russia and are shipped from Novorossiysk and Ust-Luga as KEBCO grade crude.

If you are reading this story on the Bloomberg terminal, click here for a link to a PDF file of four-week average flows from Russia to key destinations.

--With assistance from Sherry Su.

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04/01/2024 05:50:47 [BN] Bloomberg News

Russia Plans to Cut April Seaborne Diesel Exports to 5-Month Low

- Daily flows from key Russian ports seen down 21% from March
- Diesel flows shrink as Ukrainian drones hit Russian refineries

By Bloomberg News

(Bloomberg) -- Russia plans to reduce daily diesel exports from key western ports in April to the lowest in five months, after Ukrainian drone attacks on refineries and seasonal maintenance sharply lowered crude processing rates.

Diesel loadings from the nation's three major ports on the Black and Baltic Seas, including some volumes originating in Belarus, are set to fall to around 2.29 million tons this month, according to industry data seen by Bloomberg.

That equates to just over 569,000 barrels a day, down 21% compared with actual daily exports of about 724,000 barrels from the same ports in March, calculations based on data from intelligence firm Kpler show.

Russia is cutting seaborne diesel supplies after weekly crude-processing rates dropped to a 10-month low following the Ukrainian drone attacks as the war between the two nations entered its third year. Seasonal maintenance that is set to last into summer, temporarily reducing crude throughput at some Russian refineries further down, is also putting pressure on the nation's diesel flows.

Russia no longer sends diesel to Europe due to Western energy sanctions. Yet lower flows from one of the word's top producer of the fuel is set to raise volatility in the market that's already been affected by attacks on shipping in the Red

Sea and regional refinery outages.

Diesel Loading Plans, millions of tons	April
Baltic port of Primorsk	1.603
Baltic port of Vysotsk	0.211
Black Sea port of Novorossiysk	0.475

So far, Russia has no plans to ban diesel exports, Deputy Prime Minister Alexander Novak said Friday, according to Russian newswires. "We produce enough diesel, twice as much as the domestic market needs," Novak said in Moscow, according to state news agency Tass. If Russia were to impose the ban, the nation's refining industry would face overstocking, he said.

The diesel-export plan for April seen by Bloomberg only shows flows delivered to the three key domestic ports by pipeline. It doesn't include smaller volumes sent to export outlets by rail and outside of Transneft PJSC's oil-product pipeline system. Actual flows may differ, depending on the weather and demand from foreign customers.

Transneft, which compiles the loading schedules, did not immediately respond to a Bloomberg request for comment.

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https://www.opec.org/opec_web/en/press_room/7319.htm

53rd Meeting of the Joint Ministerial Monitoring Committee

No 04/2024
Vienna, Austria
03 Apr 2024

The 53rd Meeting of the Joint Ministerial Monitoring Committee (JMMC) took place via videoconference on Wednesday, 03 April 2024.

The JMMC reviewed the crude oil production data for the months of January and February 2024 and noted the high conformity for participating OPEC and non-OPEC countries of the Declaration of Cooperation (DoC).

The Committee welcomed the Republic of Iraq and the Republic of Kazakhstan pledge to achieve full conformity as well as compensate for overproduction. The Committee also welcomed the announcement by the Russian Federation that its voluntary adjustments in the second quarter of 2024 will be based on production instead of exports.

Participating countries with outstanding overproduced volumes for the months of January, February and March 2024 will submit their detailed compensation plans to the OPEC Secretariat by 30 April 2024.

The Committee will continue to monitor the conformity of the production adjustments decided upon at the 35th ONOMM held on 4 June 2023, and the additional voluntary production adjustments announced by some participating OPEC and participating non-OPEC countries in April 2023, and the subsequent adjustments in November 2023 and February 2024.

The Committee will continue to closely assess market conditions and noted the willingness of the DoC countries to address market developments and their readiness to take additional measures at any time building on the strong cohesion between OPEC and participating non-OPEC oil-producing countries.

The next meeting of the JMMC (54th) is scheduled for 01 June 2024.

https://www.presstv.ir/Detail/2024/04/07/723239/Iran-general-Rahim-Safavi-Israel-embassy

No Israeli embassy is safe anymore; resistance ready to strike: Top Iran general

Sunday, 07 April 2024 10:51 AM **[Last Update: Sunday, 07 April 2024 10:53 AM]**

Major General Yahya Rahim Safavi, a top military adviser to Leader of the Islamic Revolution Ayatollah Seyyed Ali Khamenei (Photo by Tasnim news agency)

None of the embassies of the Israeli regime are safe anymore, a top military adviser to the Leader of the Islamic Revolution Ayatollah Seyyed Ali Khamenei has warned.

In remarks on Sunday, Major General Yahya Rahim Safavi said the Leader promised a slap on the face of the Israeli regime such that the regime will regret attacking Iran's consulate in Syria, adding that the Resistance Front is fully prepared to deliver on that promise.

"We have to wait and see what will happen," the general said.

"None of the Zionist regime's embassies are safe anymore, and therefore, it has so far closed down 28 of its embassies out of fear," he added.

Rahim Safavi, a former chief commander of the Islamic Revolution Guards Corps, further said that Israeli settlers are living in fear due to the reckless attack on Iran's consulate.

"They dream of dying every night and they are the most fearful creatures," he stated.

Leader of the Islamic Revolution Ayatollah Seyyed Ali Khamenei says brave Iranian men will "punish" Israel and make the evil regime "regret" its crime of assassinating military advisors in Syria.

On Monday afternoon, Israeli warplanes bombed the consular annex of Iran's embassy in the Syrian capital of Damascus.

The air raid killed 13 people, including seven members of the Islamic Revolution Guards Corps (IRGC) who were on an advisory mission to Syria.

Iranian officials have emphasized the country's right to deliver a firm response to the Israeli crime that violated all international obligations and conventions.

https://www.irna.ir/news/85432413/%D8%A7%D9%85%DB%8C%D8%B1%D8%B9%D8%A8%D8%AF%D8%A7%D9%84%D9%84%D9%87%DB%8C%D8%A7%D9%86-%D9%BE%DB%8C%D8%A7%D9%85-%D9%85%D9%87%D9%85%DB%8C-%D8%A8%D9%87-%D8%AF%D9%88%D9%84%D8%AA-%D8%A2%D9%85%D8%B1%DB%8C%DA%A9%D8%A7-%D8%A7%D8%B1%D8%B3%D8%A7%D9%84-%D8%B4%D8%AF

April 3, 2004, 2:43
Reporter code: 863
News Code: 85432413

Warning: Important message was sent to the US government.

TEHRAN, IRNA - Iranian Foreign Minister Hossein Amirabdollahian announced the summoning of the Swiss Embassy Chargé d'affaires in Tehran to the Foreign Ministry following Monday's attack by the Zionist regime on the consular section of the Islamic Republic of Iran embassy in Damascus, saying that an important message was sent to the US government as a supporter of the Zionist regime, saying the United States must be held accountable.

The Iranian Foreign Minister wrote on social media channel X: "Following the terrorist attack on the diplomatic building of the Islamic Republic of Iran Consulate in Damascus and the martyrdom of several of our country's official military advisers, the Swiss embassy as the guardian of U.S. interests in Iran, at 00:00 p.m. He was called to the State Department by the Director General of the United States this Tuesday morning.

Amir Abdollahian added: In this summoning, the scale of the terrorist attack and the crime of the Israeli regime was explained and the responsibility of the US government was emphasized.

Emphasizing that an important message was sent to the US government as a supporter of the Zionist regime, the Foreign Minister said, "America must be held accountable."

Hussein Amir Abdollahian, the foreign minister of our country, also spoke with Hussein Ebrahim Taha by telephone an hour ago, calling for appropriate and immediate action and response of the Organization of Islamic Cooperation against the Zionist regime's terrorist attack on the Consular Section of the Embassy of the Islamic Republic of Iran in Damascus.

The Iranian Foreign Minister Amir Abdollahian spoke with Hossein Ebrahim Taha, the secretary general of the Organization of Islamic Cooperation (OIC) in a phone call yesterday evening (Monday) by the criminal Zionist regime against our country's consulate in Damascus.

In this call, the Iranian Foreign Minister expressed disgust and condemnation of the criminal attack by the Zionist regime against our country's diplomatic sites, which has taken place in violation of all rules of international law and the Convention on Diplomatic and Consular Rights, and called for appropriate and immediate action and response of the Organization of Islamic Cooperation against this crime of the Israeli regime.

The secretary general of the Organization of Islamic Cooperation also referred to the full history of crime of the Zionist regime and the severe condemnation of the new crime of this regime against diplomatic sites, expressed solidarity with the government and nation of our country and offered condolences to the families of the martyrs of this criminal attack and expressed sympathy.

Hussein Ibrahim Taha emphasized the responsibility of the Organization of Islamic Cooperation in this regard.

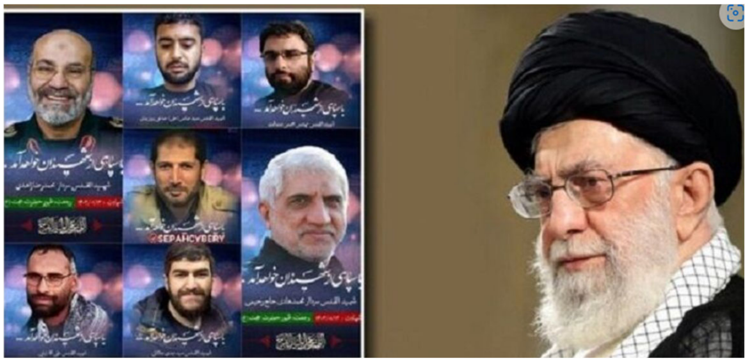
According to IRNA, the public relations of the entire Islamic Revolutionary Guard Corps (IRGC) announced in a statement hours ago: "Following the unrecoverable defeats of the wolf-like Zionist regime against the resistance of Palestine and the resistance of the people of Gaza and the humiliation of the steel will of the fighters of the Islamic Resistance Front in the region, hours ago (on the evening of Monday, April 2nd, 1403), the planes of this fake regime in a new crime targeted the building of the consulate of the Islamic Republic of Iran in Damascus. As a result of this crime, General Rashid, the defender of the shrine of Brigadier General Mohammad Reza Zahedi and Brigadier General Mohammad Hadi Haji Rahimi, one of the commanders, veterans and honorable veterans of the Holy Defense and senior military advisers of Iran in Syria and five of the officers along with them were martyred.

[LINK]

The Commander of the Faithful and the Commander of the Faithful

The evil Zionist regime will regret this crime.

April 3, 2004, 13:11
News Code: 85432891



Tehran, IRNA - In a message on the occasion of the attack on the Iranian consulate in Syria and the martyrdom of Maj. Gen. Zahedi and his comrades, the Supreme Leader of the Islamic Revolution emphasized that we will regret the usurping and hated Zionist regime of this crime and the like.

In a message on the occasion of the martyrdom of General Rashid Islam, Maj. Gen. Mohammad Reza Zahedi and a group of his comrades by the usurping and hated Zionist regime, Ayatollah Khamenei emphasized in a message on the occasion of the martyrdom of General Rashid Islam, and a group of his comrades by the usurping and hated Zionist regime.

The message of the Leader of the Islamic Revolution is as follows:

In the name of Allah, the Beneficent, the Merciful, the Commander of the Faithful and devoted to Islam, the Maj. Gen. Mohammad Reza Zahedi, were martyred along with his noble comrade General Mohammad Hadi Haj Rahimi, with the crime of the usurping and hated Zionist regime. Peace, mercy, and peace be upon them and those who are martyred in this incident, and curse the leaders of the ruthless regime and the aggressor.

Our Savior is the Savior of our people ،and they are now in the presence of God ،and they are in the presence of God.

Since the 1980s, Sardar Zahedi had been waiting for martyrdom in the fields of danger and struggle. They have lost nothing and have received their reward, but their loss is heavy for the Iranian nation, especially those who know them.

The evil regime will be punished by our brave men. We will be able to forgive them for their sins and the power of God.

Peace be upon you.
Seyyed Ali Khamenei
3 April 1403

[LINK]

Chairman: This crime will not go unanswered.

Tehran, IRNA – In response to the terrorist crimes of the Zionist regime, the president reiterated: "Zionists should know that with such inhumane actions, they will never achieve their sinister goals, and day by day they will witness the strengthening of the resistance front and hatred and hatred of free nations against their illegitimate nature, and this cowardly crime will not go unanswered."

According to the **IRNA** government, **Seyyed Ebrahim Raisi** in a statement condemning the inhumane invasion and blatant violation of international regulations by the Zionist regime in the attack on our consulate building in Damascus, stated: "These Mujahedeen generals, who were commanders, warriors and veterans of the holy defense era, were in the position of senior advisors in defense of the shrine of the Ahlulbayt, and purity against peace and in the protection of high Islamic and human values. They were in Syria and proudly joined the caravan of martyrs.

The President's statement is as follows;

Praise the Lord and the Savior.

Once again, in a terrorist crime and in gross violation of international law, the evil hands of the usurping Zionist regime were stained with the blood of several of our country's generals and officers.

The Israeli regime's aggressive and despicable act in the attack on the consulate building of the Islamic Republic of Iran in Damascus led to the martyrdom of Brigadier General Mohammad Reza Zahedi and Brigadier General Mohammad Hadi Haji Rahimi and five of their companions. These Mujahedeen generals, who were commanders, warriors and veterans of the holy defense, were present as senior advisors in defense of the shrine of Ahl al-Baysmat and purity of peace and in protecting high Islamic and human values in Syria and proudly joined the caravan of martyrs.

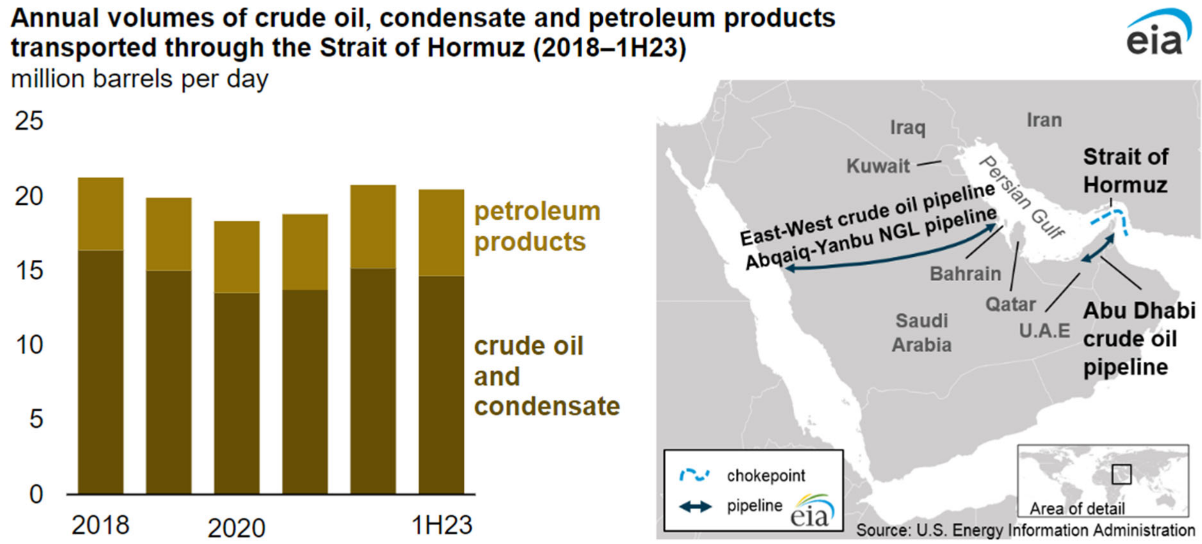
Condemning this inhumane invasion that is a clear violation of international law, I express my condolences to the martyrs of these children of the Islamic homeland to the Supreme Leader, the martyr-breeding nation of Iran, the martyrs of the Islamic Revolutionary Guard Corps, and especially their honorable families.

After repeated defeat and failure against the faith and will of the Resistance Front, the Zionist regime has put blind assassinations on the agenda in the struggle to save itself, but it must know that with such inhumane measures it will never achieve its ominous goals, and day by day it has witnessed the strengthening of the resistance front and the hatred and hatred of free nations against its illegitimate nature, and this cowardly crime will not go unanswered.

Seyyed Ebrahim Raeesi President of the Islamic Republic of Iran https://www.eia.gov/todayinenergy/detail.php?id=61002

NOVEMBER 21, 2023

The Strait of Hormuz is the world's most important oil transit chokepoint



Data source: U.S. Energy Information Administration analysis based on Vortexa tanker tracking and FACTS Global Energy
Note: 1H23=first half of 2023

The Strait of Hormuz, located between Oman and Iran, connects the Persian Gulf with the Gulf of Oman and the Arabian Sea. The Strait of Hormuz is the world's most important oil chokepoint because large volumes of oil flow through the strait. In 2022, its oil flow averaged 21 million barrels per day (b/d), or the equivalent of about 21% of global petroleum liquids consumption. In the first half of 2023, total oil flows through the Strait of Hormuz remained relatively flat compared with 2022 because increased flows of oil products partially offset declines in crude oil and condensate.

Chokepoints are narrow channels along widely used global sea routes that are critical to global energy security. The inability of oil to transit a major chokepoint, even temporarily, can create substantial supply delays and raise shipping costs, increasing world energy prices. Although most chokepoints can be circumvented by using other routes, which often add significantly to transit time, some chokepoints have no practical alternatives.

Between 2020 and 2022, volumes of crude oil, condensate, and petroleum products transiting the Strait of Hormuz rose by 2.4 million b/d as oil demand recovered after the economic downturn from the COVID-19 pandemic. In the first half of 2023, shipments of crude oil and condensates dropped because OPEC+ members implemented crude oil production cuts starting in November 2022. Flows through the Strait of Hormuz in 2022 and the first half of 2023 made up more than one-quarter of total global seaborne traded oil. In addition, around one-fifth of global liquefied natural gas trade also transited the Strait of Hormuz in 2022.

Volume of crude oil, condensate, and petroleum products transported through the Strait of Hormuz (2018–1H23)
million barrels per day

	2018	2019	2020	2021	2022	1H23
Total oil flows through Strait of Hormuz	**21.3**	**19.9**	**18.3**	**18.8**	**20.8**	**20.5**
Crude oil and condensate	16.4	15.0	13.5	13.7	15.2	14.7
Petroleum products	4.9	4.9	4.8	5.1	5.6	5.8
World maritime oil trade	**77.4**	**77.1**	**71.9**	**73.2**	**75.2**	**76.3**
World total petroleum and other liquids consumption	**100.1**	**100.9**	**91.6**	**97.1**	**99.6**	**100.3**
LNG flows through Strait of Hormuz (billion cubic feet per day)	**10.3**	**10.6**	**10.4**	**10.6**	**10.9**	**10.8**

Data source: U.S. Energy Information Administration, *Short-Term Energy Outlook*, and U.S. Energy Information Administration analysis based on Vortexa tanker tracking and FACTS Global Energy
Note: World maritime oil trade excludes intra-country volumes except those volumes that transit the Strait of Hormuz. LNG=liquefied natural gas. 1H23=first half of 2023.

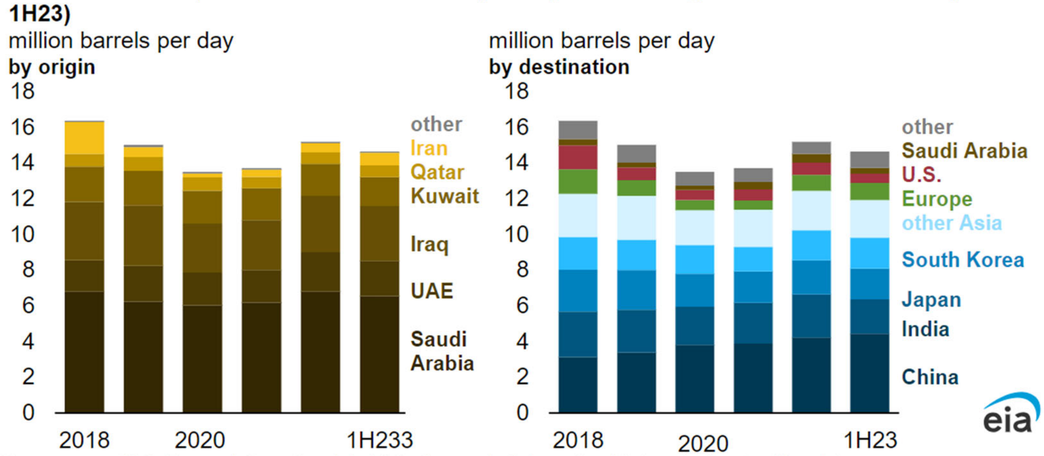
Only Saudi Arabia and the United Arab Emirates (UAE) have operating pipelines that can circumvent the Strait of Hormuz. Saudi Aramco operates the 5-million-b/d East-West crude oil pipeline and temporarily expanded the pipeline's capacity to 7 million b/d in 2019 when it converted some natural gas liquids pipelines to accept crude oil. The UAE links its onshore oil fields to the Fujairah export terminal on the Gulf of Oman with a 1.5 million b/d pipeline.

Iran inaugurated the Goreh-Jask pipeline and the Jask export terminal on the Gulf of Oman with a single export cargo in July 2021. The pipeline's capacity was 0.3 million b/d at that time, although Iran has not used the pipeline since then. We estimate that around 3.5 million b/d of effective unused capacity from these pipelines could be available to bypass the strait in the event of a supply disruption.

Based on tanker tracking data published by Vortexa, Saudi Arabia moves more crude oil and condensate through the Strait of Hormuz than any other country, most of which is exported to other countries. Around 0.5 million b/d transited the strait in 2022 from Saudi ports in the Persian Gulf to Saudi ports in the Red Sea.

We estimate that 82% of the crude oil and condensate that moved through the Strait of Hormuz went to Asian markets in 2022. China, India, Japan, and South Korea were the top destinations for crude oil moving through the Strait of Hormuz to Asia, accounting for 67% of all Hormuz crude oil and condensate flows in 2022 and the first half of 2023.

Annual volumes (crude oil and condensate) transported through the Strait of Hormuz (2018–1H23)



Data source: U.S. Energy Information Administration analysis based on Vortexa tanker tracking data
Note: 1H23=first half of 2023.

In 2022, the United States imported about 0.7 million b/d of crude oil and condensate from Persian Gulf countries through the Strait of Hormuz, accounting for about 11% of U.S. crude oil and condensate imports and 3% of U.S. petroleum liquids consumption. U.S. crude oil imports from countries in the Persian Gulf have fallen by half since 2018 as domestic production has increased.

Principal contributors: Candace Dunn, Justine Barden

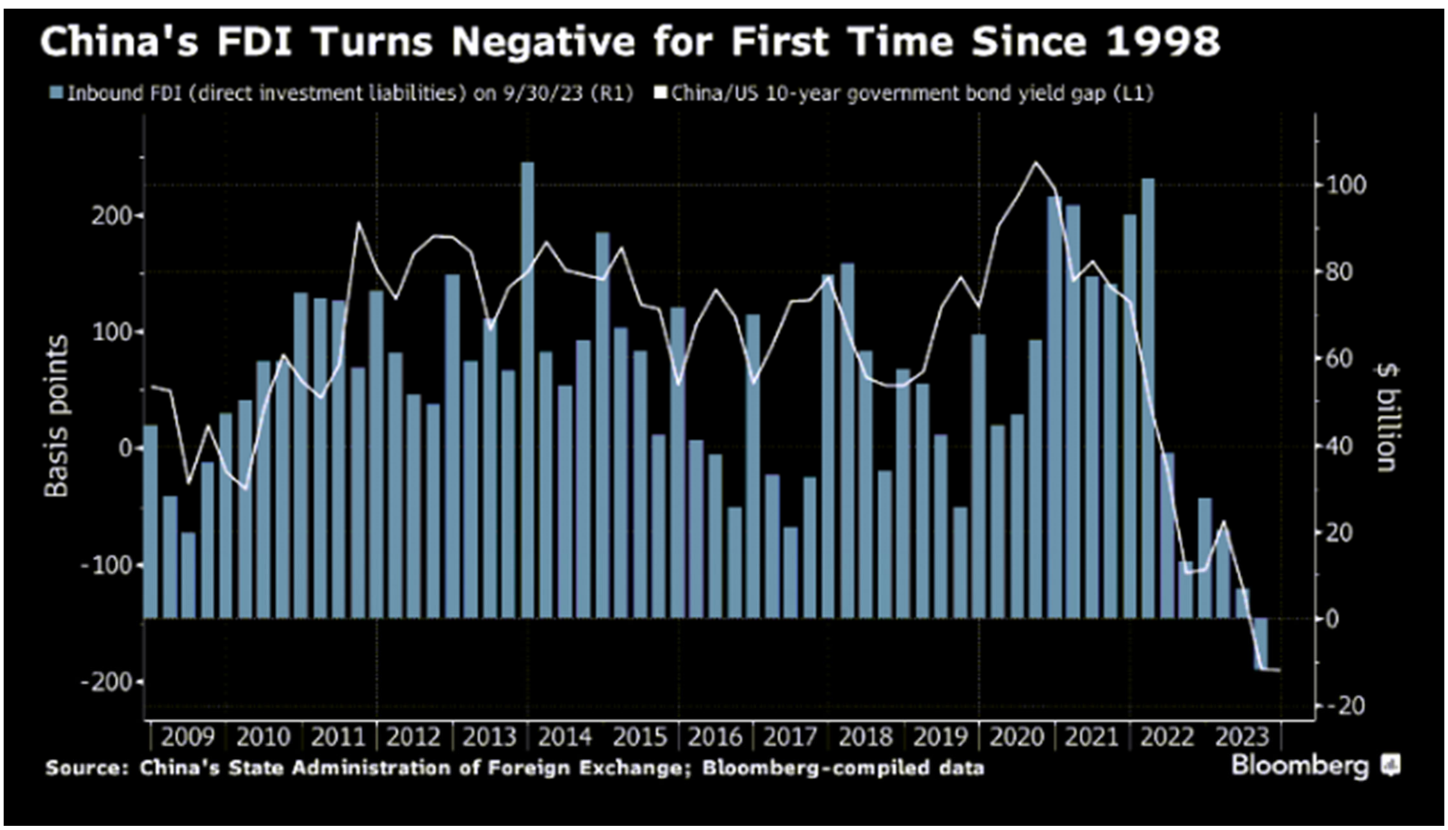
China Is Having a Hard Time Wooing Foreign Investors Back (1)
2023-11-08 11:37:38.881 GMT

By Bloomberg News
(Bloomberg) -- China is struggling in its attempt to lure foreigners back as data shows more direct investment flowing out of the country than coming in, suggesting companies may be diversifying their supply chains to reduce risks.

Direct investment liabilities in the country's balance of payments have been slowing in the last two years. After hitting a near-peak value of more than $101 billion in the first quarter of 2022, the gauge has weakened nearly every quarter since. It fell $11.8 billion in the July-to-September period, marking the first contraction since records started in 1998.

"It's concerning to see net outflows where China's doing its best at the moment to try and open — certainly the manufacturing sector — to new inflows," said Robert Carnell, regional head of research for Asia-Pacific at ING Groep NV.

"Maybe this is the beginning of a sign that people are just increasingly looking at alternatives to China for investment."



The Chinese government has embarked on a big push in recent months to lure foreign investment back to the country. On Wednesday, the Ministry of Commerce asked local governments to clear discriminatory policies facing foreign companies in a bid to stabilize investment confidence.

It cited the need to ensure subsidies for new energy vehicles are not limited to domestic brands as one example. In

some industries, foreign firms wait longer and are subject to more rigorous reviewing process when applying for licenses.
In August, the internet regulator met with executives from dozens of international firms to ease concerns about new data rules. The government has also pledged to offer overseas companies better tax treatment and make it easier for them to obtain visas.
But Beijing's pledges have rung hollow for some firms, with foreign business groups decrying "promise fatigue" amid skepticism about whether meaningful policy support is forthcoming. They also have incentive to repatriate earnings overseas because of the wide gap in interest rates between China and the US, which may be pushing them to seek higher returns elsewhere.
The FDI outflows are adding pressure on the onshore yuan, which has hit the weakest level since 2007 earlier this year. China's benchmark 10-year government bond yield is trading at 191 basis points below that of comparable US Treasuries, versus an average premium of about 100 basis points over the past decade.
"Decoupling" or "derisking" from China is an important reason for the declining FDI data reported by the State Administration of Foreign Exchange, according to Louis Kuijs, chief economist for Asia Pacific at S&P Global Ratings. Concerns about geopolitics and US-China relations were cited as major reasons for foreign corporate pessimism in a survey published in September by the American Chamber of Commerce in Shanghai.
Companies have cited various countries in the region as destinations for their supply chain shifts. Japan, India and Vietnam were floated as "top destinations gaining more attraction" in a spring survey of companies by UBS Group AG. A March AmCham report pointed to developing Asia and the US as places where members were considering moving capacity to from China.

Widespread Consequences

The lack of investment among global firms in China may have far reaching effects on the world's second-largest economy, especially as it tries counter US curbs on access to advanced technology.
Aside from geopolitical risks, companies had also been pulling back on investment in China last year as the country rolled out pandemic restrictions. While those curbs have been removed, firms are still contending with other challenges from rising manufacturing costs in China and regulatory hurdles as Beijing scrutinizes activity at foreign corporations due to national security concerns.
"Some of the most damaging things have been the abrupt regulatory changes that have taken place," said Carnell, pointing to this year's anti-espionage campaign, which resulted in some firms having their offices raided by local authorities.
"Once you damage the sort of perception of the business

environment, it’s quite difficult to restore trust. I think it will take some time.”

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Read More About Foreign Firms in China:

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Foreign companies make up less than 3% of the total number of corporations in China, but contribute to 40% of its trade, more than 16% of tax revenue and almost 10% of urban employment, state media has reported. They’ve also been key to China’s technological development, with foreign investment in the country’s high-tech industry growing at double-digit rates on average since 2012, according to the official Xinhua News Agency.

“A decline in trade and investment links with advanced economies will be a particularly significant headwind for a catching up economy such as China, weighing on productivity growth and technological progress,” Kuijs said.

Limited Optimism

There are some reasons for optimism in the coming weeks and months. President Joe Biden is set to meet with his Chinese counterpart Xi Jinping on the sidelines of the Asia-Pacific Economic Cooperation summit in San Francisco later this month, which may help stabilize strained bilateral ties.

It would be helpful if increased communication yielded some “more stability and clarity on the geopolitical front,” Kuijs said, though he added it is unlikely the US will meaningfully change its policy stance.

Some economists also argue that FDI will stabilize once the China-US yield differential narrows. They also point to data on actually utilized FDI published by the Ministry of Commerce, which holds up better the SAFE data: Those figures show FDI fell 8.4% in the first nine months of this year from the same time period in 2022, to 920 billion yuan.

"I think things are not as bad as they seem from the SAFE data, otherwise policy tightening for China's capital account management would be witnessed," said Bruce Pang, chief economist for Greater China at Jones Lang LaSalle Inc.

In any case, China still needs to convince investors that they are welcome in the country.

"The more that it can offer a stable, conducive policy environment, the better it would be for FDI," Kuijs said. "That includes minimizing the impact of national security-related measures on the economy and sentiment."

--With assistance from Wenjin Lv and Evelyn Yu.

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Caixin China General Manufacturing PMI®

Operating conditions improve at quickest pace since February 2023

Manufacturing sector conditions in China further improved at the end of the first quarter of 2024, according to the latest PMI® data. This was driven by greater inflows of new work, including from abroad. In turn, Chinese manufacturers increased production, while also raising their purchasing levels amid improved optimism. That said, a cautious stance was maintained with regards to staffing levels.

Meanwhile input costs fell for the first time in eight months, enabling Chinese manufacturers to further lower selling prices in a bid to drive sales.

The headline seasonally adjusted Purchasing Managers' Index™ (PMI) – a composite indicator designed to provide a single-figure snapshot of operating conditions in the manufacturing economy – rose to 51.1 in March, up from 50.9 in February. This signalled a fifth successive monthly improvement in the health of the sector and at the most pronounced pace in 13 months.

Supporting the latest advancement of manufacturing sector health was better demand conditions. Incoming new orders, including export orders, grew at accelerated rates as both domestic and external market conditions improved according to panellists. Although modest, the rate at which new export orders rose was the fastest in just over a year.

As a result of a quicker rise in new orders, Chinese manufacturers raised their production in March. Adjusted for seasonal factors, the rate at which manufacturing output recovered to the fastest since last May. Nonetheless there was a renewed accumulation of backlogged work in March, albeit at a marginal pace.

Employment levels declined again in March. While resignations partly accounted for the decline in headcounts, comments from panellists further indicated that firms were cautious about hiring in an attempt to rein in costs.

Purchasing activity meanwhile rose across the Chinese manufacturing sector in line with growth in new work. Firms also opted to raise their holdings of raw materials and semi-finished items to meet current and future production needs. In contrast, the level of post-production inventories fell for a second successive month as rising new orders led to increased outbound shipments of goods for the fulfilment of orders.

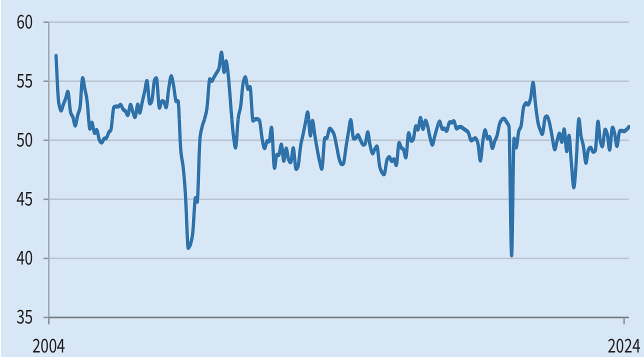
Turning to prices, average input costs fell for the first time since July 2023, albeit only marginally. Survey respondents often linked the reduction in input prices to a fall in raw material costs.

In turn, Chinese manufacturers lowered their selling prices for a third straight month and at the most pronounced pace in eight months. Export charges similarly declined in March and at a modest pace that was comparable with overall selling prices. Firms indicated being able to reduce selling prices with lower costs, which further helped to drive sales at the end of the first quarter of 2024.

Overall optimism among Chinese manufacturers improved for a third straight month in March. Firms pinned hopes of rising manufacturing activity upon a better economic outlook. The level of business confidence was the highest seen since April 2023.

China General Manufacturing PMI

sa, >50 = improvement since previous month



Sources: Caixin, S&P Global PMI

Key findings:

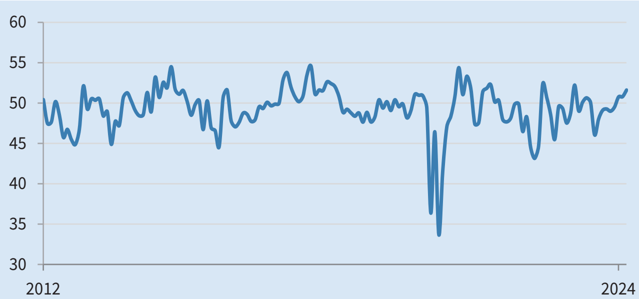
Production expands at most pronounced pace in ten months

Business confidence rises to highest in just under a year

Selling prices fall at fastest pace since last July amid lower costs

New Export Orders Index

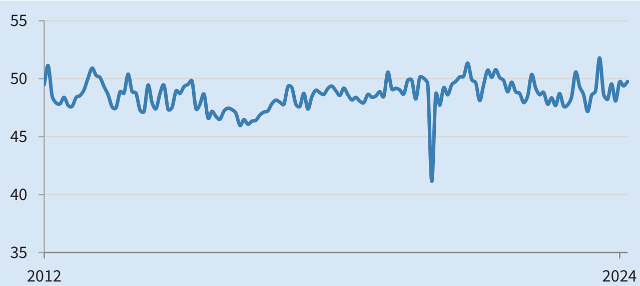
sa, >50 = growth since previous month



Sources: Caixin, S&P Global PMI

Employment Index

sa, >50 = growth since previous month



Sources: Caixin, S&P Global PMI

Commenting on the China General Manufacturing PMI® data, Dr. Wang Zhe, Senior Economist at Caixin Insight Group said:

"The Caixin China General Manufacturing PMI ticked up 0.2 points from February to 51.1 last month, reaching its highest level since February 2023. The index remained in the expansion zone for a fifth straight month, indicating a continued improvement in the sector.

"Both supply and demand expanded at a faster pace amid the market upturn. In March, growth in manufacturers' output and total new orders accelerated, with the former hitting a 10-month high. External demand also picked up pace thanks to the recovery in the global economy, pushing the gauge for new export orders to its highest level since February 2023.

"Employment edged lower. The labor market remained contracted despite the expansion of supply and demand. Manufacturers showed reluctance to fill vacant roles out of cost concerns. The corresponding measure remained in contraction for the seventh consecutive month, albeit higher than in February. Meanwhile, backlogs of work rose on increased demand.

"Prices remained low. A drop in raw material prices reduced production costs for manufacturers, providing leeway for them to lower prices amid fierce market competition. Both gauges for input costs and output prices reached new lows since July 2023.

"Supplier delivery times were shortened due to a quick recovery in logistics, which had been affected by poor weather conditions in some regions, bringing the corresponding gauge back to expansion. Meanwhile, following the market upturn, manufacturers were more willing to increase their purchases, while the gauge for raw material inventories recorded its highest level since November 2020.

"Market optimism continued to grow, with the measure tracking future output expectations rising for the third straight month. Surveyed companies expected sustained increases in production and sales over the coming year.

"Overall, the manufacturing sector continued to improve in March, with expansion in supply and demand accelerating, and overseas demand picking up. Manufacturers increased purchases and raw material inventories amid continued improvement in business optimism. However, employment remained in contraction and a depressed price level worsened.

"The economic performance in the first two months of this year was better than expected, while the Caixin manufacturing PMI has remained in expansionary territory for five consecutive months. This indicates a generally stable and positive economic recovery.

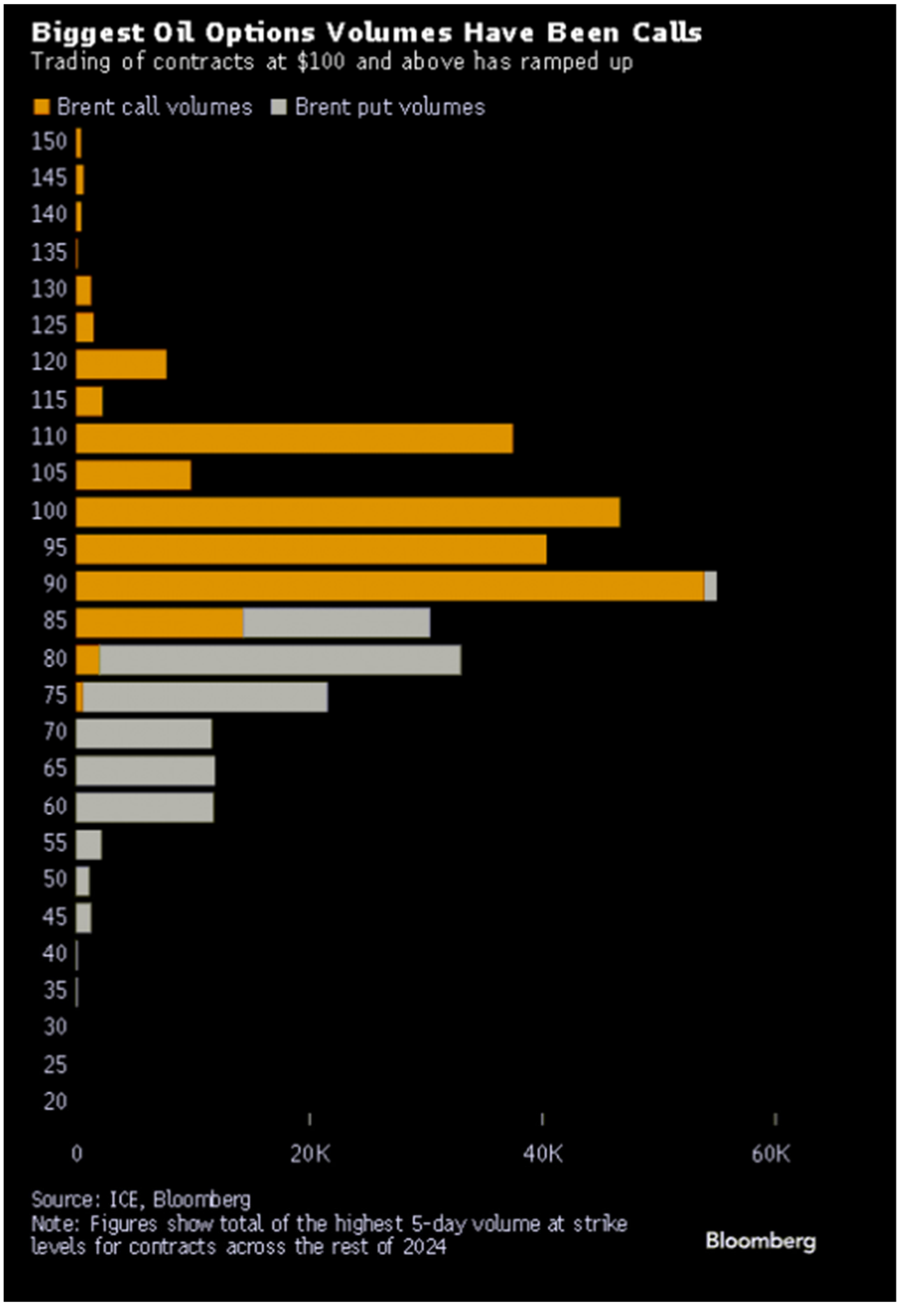
"However, the economy still faces headwinds with prevalent uncertainties and unfavorable factors. Downward economic pressures persist, employment remains subdued, prices remain low, and insufficient effective demand has not been fundamentally resolved, underscoring the need to further boost domestic and external demand.

"A slew of policies introduced earlier this year to stabilize growth are gradually having an effect. Given the current economic hurdles and an ambitious goal for economic growth this year, consistent efforts should be made to accelerate growth while improving the quality and efficiency of economic development."

Bloomberg
Oil's Under-the-Hood Signals Tell Tale of Very Bullish Market
2024-04-05 07:31:06.724 GMT

By Yongchang Chin, Alex Longley and Devika Krishna Kumar
(Bloomberg) -- The global oil market has gone from languid to lively in the space of a few weeks, with Brent futures blowing past the key $90-a-barrel threshold as critical gauges flash steadily more bullish signals.
The surge in headline prices — with Brent now up 18% this year — has been driven by a combination of supply constraints including OPEC+ curbs, robust demand, and wider geopolitical risks, especially in the Middle East. Many refined-product markets are also strong, with gasoline posting big gains.
As traders weigh the possibility that $100-a-barrel crude could make a comeback, the momentum is diverting their attention from the possibility of a cease-fire in the Middle East, as well as the impact of higher prices on refinery margins. Here's a rundown of the main indicators that are painting a more rosy picture for bulls.

$100 Options
Options markets have taken on a stronger tone as geopolitical tensions ratcheted higher, with Tehran vowing retaliation against Israel after an airstrike killed an Iranian general. Call options, which profit when prices rise, are trading at a rare premium to bearish puts, and volumes for protection against a spike in prices — even beyond $100 — have surged.
"What is underpinning the move is financial markets," Ed Morse, a senior adviser at Hartree Partners, said in a Bloomberg Television interview. "With the rise in tensions in the Middle East, there certainly is an increase in call buying for Brent."



Spreads Surging

The shape of the futures curve is now pointing to strength. The spread between the nearest two December contracts, a favored trade for speculators, is back to the widest since October. That represents increasing confidence in a tight market, something that's also supported by firmness in pricing signals at the key US hub in Cushing, Oklahoma. There, nearby prices recently traded at large premiums to later ones, while the so-called WTI cash roll traded outside of its usual window, suggesting inventories are unexpectedly low.

Technical Signs

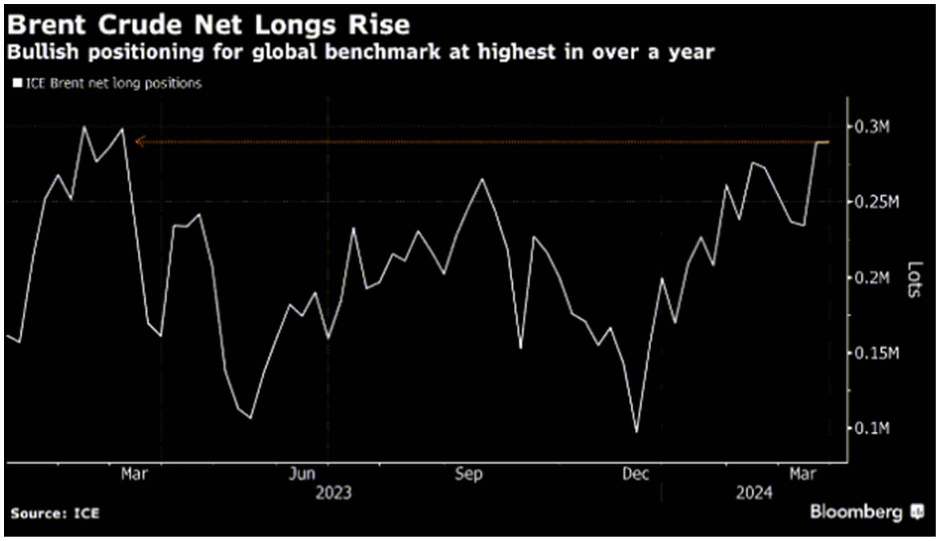
Following its breakout from the narrow range early in the year, Brent's technical picture looks much more solid. On Thursday, the global benchmark's 50-day moving average topped its 200-day counterpart for the first time since August. That pattern could spur additional buying from trend-following funds. Prices may also be forming a double-bottom that could pave the way for $112, Bank of America analyst Paul Ciana wrote in a note.

However, Brent's run of gains have also lifted its 14-day relative-strength index above the level of 70, a threshold that suggests to some traders the advance has been to swift and a pullback may be due.

Funds Buying

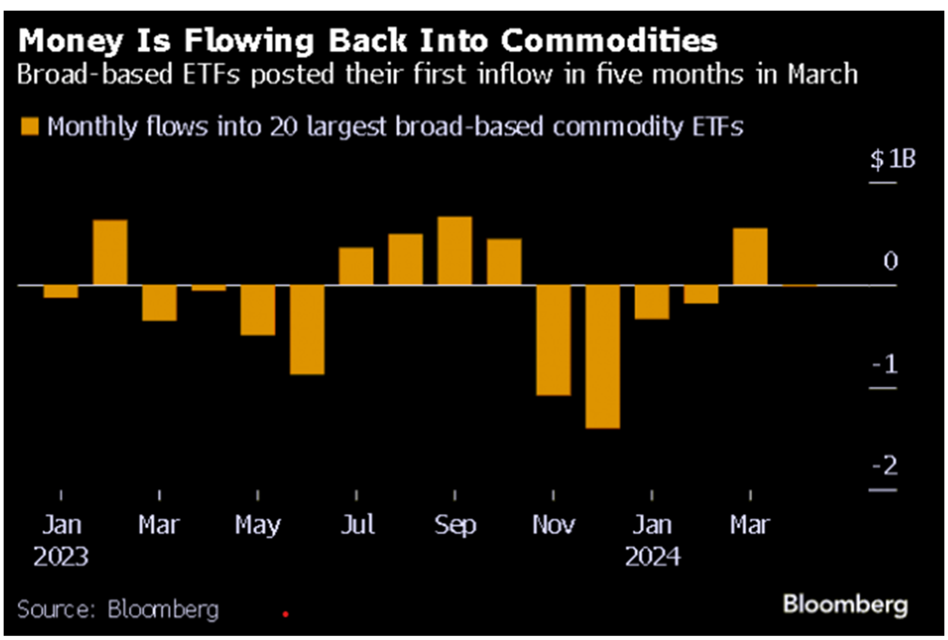
Money managers have been piling into oil as indicators improve, with positioning in Brent at the most bullish in more than a year and in US crude at the most in about five months. Trend-following algorithmic traders, known as CTAs, are now estimated to be as long as they can be in crude futures, although that can leave the market vulnerable to some short-term selling.

"Unless WTI crude prints a new high, CTA trend-followers could now be set to offload some recently added length," said Daniel Ghali, a commodity strategist at TD Securities. "Imminent buying exhaustion could easily morph into selling activity in crude oil markets."



ETF Inflows

Flows into commodity markets more broadly have also been turning positive for the first time in months as US inflation gauges remain elevated. Broad-based commodity exchange-traded funds pulled in cash in March for the first time in five months, while the largest cross-commodity product has seen a run of inflows as traders dip their toes back into markets for raw materials.



Product Margins

As crude prices advance, traders are increasingly focused on the profits refineries make from turning crude into fuels. Gasoline has been the runaway product in recent months, with benchmark futures about 33% higher this year, as refining margins also rally above seasonal averages.

Still, some traders see a hint of caution in naphtha — a product that's used to make plastics. In both Asia and Europe, margins for the fuel are at five-month lows, making that one indicator that's offering a red flag even as prices continue to power higher.

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Air Passenger Market Analysis

February 2024

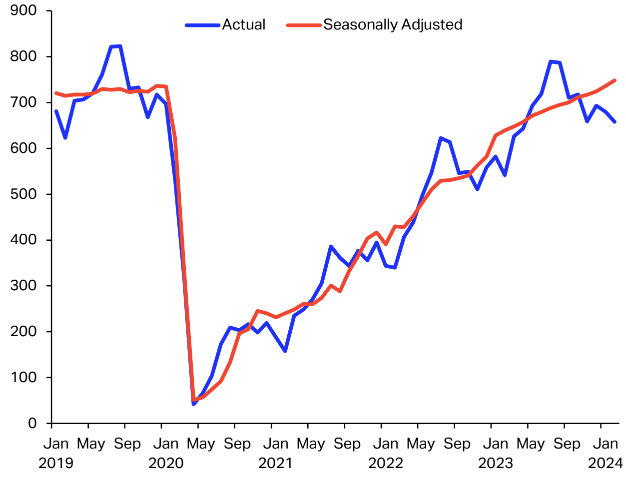
Global air traffic surpasses pre-pandemic levels in February

- In February 2024, the airline industry achieved full recovery in total passenger traffic, surpassing the 2019 threshold by 5.7%. Annual growth in Revenue Passenger-Kilometers (RPK) reached 21.5% year-on-year (YoY). Passenger load factors (PLF) improved in comparison to the previous year and settled in the vicinity of pre-pandemic levels.
- Domestic traffic grew 13.7% over 2019 levels and 15.0% over the year, reflecting the strong performance of all major markets as well as the intense travel period around the Lunar New Year that pushed PR China domestic traffic to new highs (+31.5% YoY).
- International traffic was 0.9% higher than February 2019 figures, while annual growth reached an impressive 26.3%. Asia Pacific continued to lead the regions in terms of growth, as the comeback of international travel from and to that region continued. The markets which had experienced an earlier rebound also displayed solid traffic growth this month.
- Ahead of the Lunar New Year, ticket sales significantly increased, for both domestic and international travel. This peak in demand was followed by a brief slowdown in ticket purchases. Over the month of March, ticket sales stabilized, indicating resilient demand for air travel.

Industry-wide traffic surpassed pre-pandemic levels in February

Industry-wide air passenger traffic, measured in revenue passenger-kilometers (RPK), surpassed 2019 levels in February 2024, marking the first occurrence of full global recovery in both, domestic and international, travel segments (**Chart 1**).

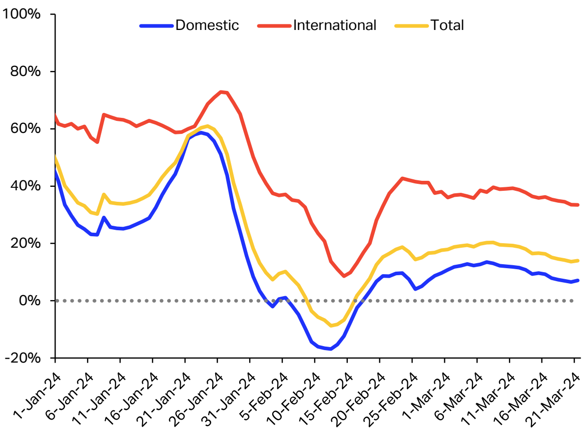
Chart 1 – Global air passengers, RPK, billions per month



Sources: IATA Sustainability and Economics, IATA Monthly Statistics

Total RPK were 5.7% higher than February 2019 figures, while international and domestic traffic saw 0.9% and 13.7% growth over the same period, respectively. Passenger load factors in all segments were also close to pre-Covid levels, indicating the return of available seat supply and passenger demand on a global scale. Compared to the previous year, total traffic increased by 21.5%. A strong recovery in all regions and important markets as well as a particularly busy month of February contributed to this outcome. Indeed, the number of ticket sales peaked in late January to early February, indicating elevated demand for air travel ahead of the key Lunar New Year period in Asia Pacific and beyond (**Chart 2**).

Chart 2 – Ticket sales by purchase date, 7-day moving average – YoY%



Sources: IATA Sustainability and Economics, IATA Monthly Statistics

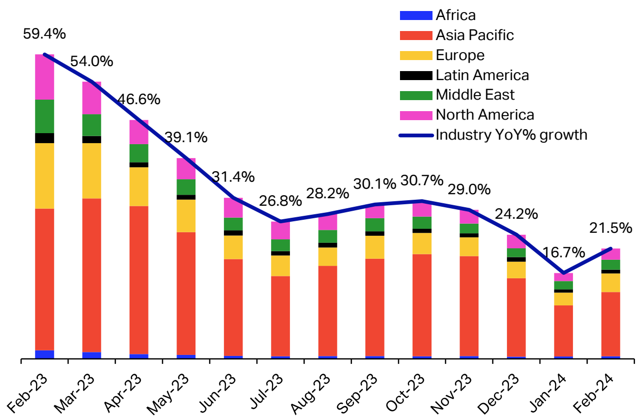
Air passenger market in detail - February 2024

	World share[1]	February 2024 (% year-on-year)			February 2024 (% ch vs the same month in 2019)			
		RPK	ASK	PLF (%-pt)	RPK	ASK	PLF (%-pt)	PLF
TOTAL MARKET	***100.0%***	**21.5%**	**18.7%**	**1.9%**	**5.7%**	**5.8%**	**-0.1%**	**80.6%**
International	*60.1%*	26.3%	25.5%	0.5%	0.9%	1.2%	-0.3%	79.3%
Domestic	*39.9%*	15.0%	9.4%	4.0%	13.7%	13.7%	0.0%	82.6%

[1]% of industry RPKs in 2023

During the event, domestic ticket sales contracted compared to the previous year, while sales for international travel remained higher than in 2023. Over the month of March, ticket sales for both travel segments remained elevated compared to the previous year while trending roughly sideways, indicating consistent high demand for air travel following the Lunar New Year break.

Chart 3 – Regional contribution to industry annual total RPK growth

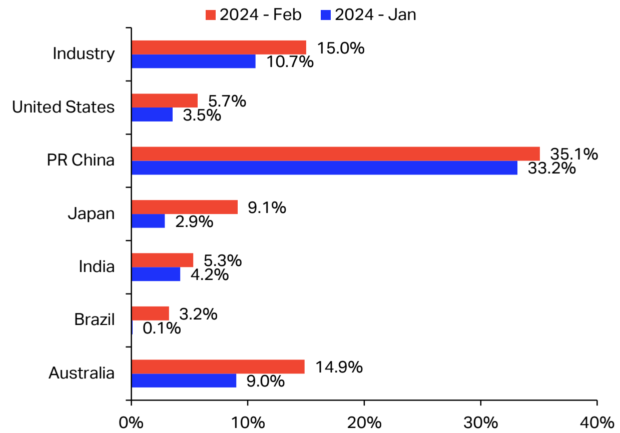


Sources: IATA Sustainability and Economics, IATA Monthly Statistics

The 21.5% uptick in year-on-year (YoY) growth of Industry-wide passenger traffic in February came after 4 months of decline. Asia Pacific was once again the region to bring the largest contribution to the industry's growth, explained by high activity in the PR China domestic market as well as the comeback of international traffic from Asia (**Chart 3**).

Domestic traffic growth accelerated in February…

Chart 4 – Domestic RPK growth by market, YoY%



Sources: IATA Sustainability and Economics, IATA Monthly Statistics

At the industry level, domestic traffic grew 15.0% YoY, reflecting the improvements in all major markets as well as the record-breaking traffic levels in PR China. Indeed, passenger flows within the country increased by 35.1% YoY in February 2024 with the highest figures in two decades for that particular month. On the other hand, domestic tourism continued to drive traffic growth in PR China, and seat capacity levels reinforced by the more frequent use of widebody aircraft (**Chart 4**).

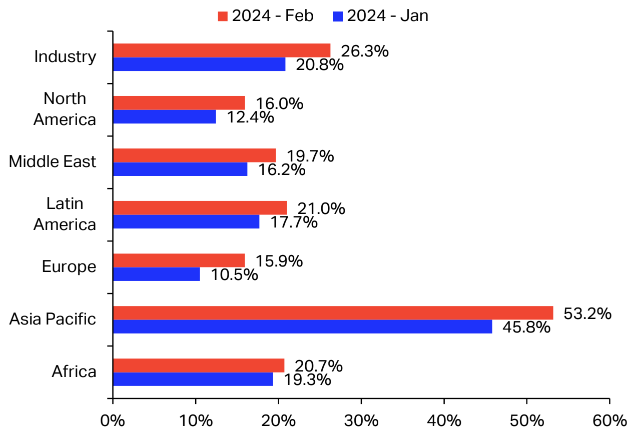
Japan domestic RPK climbed by 9.1% YoY, accelerating substantially compared to the previous month. India saw a stable rise in RPK in February with 5.3% annual growth. Passenger numbers in Australia increased by 14.9% YoY in February. In all these markets, passenger load factors were above the previous year.

The US and Brazil experienced 5.7% and 3.2% YoY growth in domestic traffic, respectively. For both markets, annual growth rates were resilient and higher than the pre-pandemic average of 2019 (**Chart 4**).

…while international traffic growth remained solid

Industry-wide international RPK reached pre-Covid levels in February while displaying uninterrupted momentum with 26.3% annual growth (**Chart 5**). This was supported by positive results across all regions, and higher YoY growth rates compared to the previous month. Also, all regions except Asia Pacific and Europe surpassed pre-pandemic levels in RPK. In these two regions, total recovery in international traffic is now imminent as Asia Pacific RPK stood 7.0% below 2019 levels in February and Europe was down only 0.2%. Annual growth ranged from 15.9% in Europe to 53.2% for Asia Pacific carriers (**Chart 5**). Asia Pacific carriers naturally took the lead in annual growth as international traffic in the region is lagging other geographic areas in the post-pandemic recovery.

Chart 5 – International RPK growth by airline region of registration, YoY%



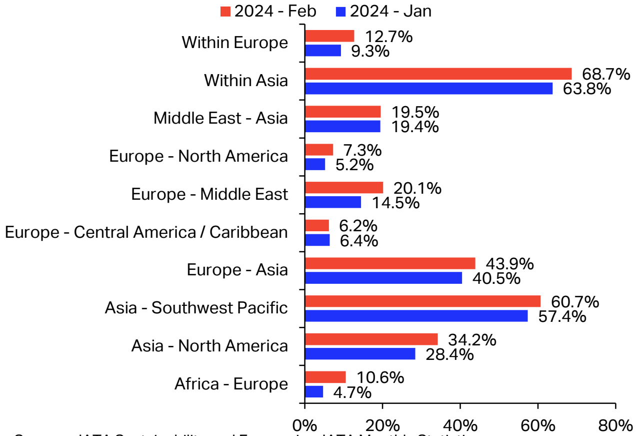
Sources: IATA Sustainability and Economics, IATA Monthly Statistics

In line with those developments, the main route areas around the Asia Pacific region did not yet achieve complete recovery to 2019 levels but displayed the highest annual growth rates (**Chart 6**). Traffic Within Asia experienced 68.7% increase in RPK, the highest among the top ten route areas in 2019. Passenger flows inside the wider Asia Pacific region took off as well, as RPK from Asia to the Southwest Pacific grew 60.7% YoY.

In contrast, international passenger numbers on the Europe – North America, Europe – Central America / Caribbean and Africa – Europe route areas saw the lowest growth, in line with the early recovery those markets experienced over the past two years. Nevertheless, these routes observed resilient growth figures that indicate consistent expansion.

Between Europe and Asia, international RPK rose by 43.9% YoY while the Europe – Middle East route area saw 20.1% growth. While the war in Ukraine continues to impact air space capacity, air traffic still experiences resilient demand in these markets.

Chart 6 – International RPK, YoY% – Top 10 route areas in 2019



Sources: IATA Sustainability and Economics, IATA Monthly Statistics

Air passenger market in detail - February 2024

	World share[1]	February 2024 (% year-on-year)				February 2024 (% year-to-date)			
		RPK	ASK	PLF (%-pt)	PLF (level)	RPK	ASK	PLF (%-pt)	PLF (level)
TOTAL MARKET	***100.0%***	**21.5%**	**18.7%**	**1.9%**	**80.6%**	**19.0%**	**16.4%**	**1.8%**	**80.2%**
Africa	*2.1%*	22.5%	24.3%	-1.1%	74.4%	20.8%	22.1%	-0.8%	74.0%
Asia Pacific	*31.7%*	37.8%	30.1%	4.7%	84.4%	35.0%	28.4%	4.0%	82.6%
Europe	*27.1%*	14.8%	14.6%	0.2%	76.1%	12.1%	11.9%	0.1%	77.1%
Latin America	*5.5%*	13.0%	10.8%	1.6%	82.7%	11.3%	7.9%	2.5%	83.9%
Middle East	*9.4%*	19.7%	18.8%	0.6%	80.8%	17.9%	17.0%	0.6%	80.4%
North America	*24.2%*	8.9%	8.8%	0.0%	79.5%	7.6%	6.6%	0.8%	79.7%
International	***60.1%***	**26.3%**	**25.5%**	**0.5%**	**79.3%**	**23.4%**	**23.1%**	**0.2%**	**79.5%**
Africa	*1.8%*	20.7%	22.1%	-0.8%	74.0%	20.0%	20.6%	-0.4%	73.8%
Asia Pacific	*14.7%*	53.2%	52.1%	0.6%	84.9%	49.4%	50.2%	-0.4%	83.8%
Europe	*23.6%*	15.9%	16.0%	0.0%	74.7%	13.0%	13.1%	-0.1%	76.0%
Latin America	*2.7%*	21.0%	18.6%	1.7%	84.2%	19.2%	15.6%	2.6%	85.2%
Middle East	*9.1%*	19.7%	19.1%	0.4%	80.8%	17.9%	17.3%	0.4%	80.3%
North America	*8.1%*	16.0%	17.6%	-1.1%	77.7%	14.1%	15.7%	-1.1%	78.6%
Domestic	***39.9%***	**15.0%**	**9.4%**	**4.0%**	**82.6%**	**12.8%**	**7.1%**	**4.1%**	**81.4%**
Dom. Australia	*0.8%*	14.9%	9.1%	3.7%	73.4%	11.9%	9.0%	1.9%	73.3%
Domestic Brazil	*1.2%*	3.2%	5.5%	-1.7%	77.5%	1.5%	1.8%	-0.3%	80.5%
Dom. China P.R.	*11.2%*	35.1%	20.5%	9.2%	84.9%	34.2%	19.8%	8.8%	82.6%
Domestic India	*1.8%*	5.3%	4.8%	0.5%	88.8%	4.8%	1.9%	2.4%	88.9%
Domestic Japan	*1.1%*	9.1%	0.9%	5.9%	79.0%	6.1%	-1.1%	5.0%	73.8%
Domestic US	*15.4%*	5.7%	4.8%	0.7%	80.2%	4.6%	2.4%	1.7%	80.0%

[1]% of industry RPKs in 2023

Note: the six domestic passenger markets for w hich broken-dow n data are available account for approximately 31.4% of global total RPKs and 78.8% of total domestic RPKs

Note: The total industry and regional grow th rates are based on a constant sample of airlines combining reported data and estimates for missing observations. Airline traffic is allocated according to the region in w hich the carrier is registered; it should not be considered as regional traffic.

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3 April 2024

Air Cargo Market Analysis

February 2024

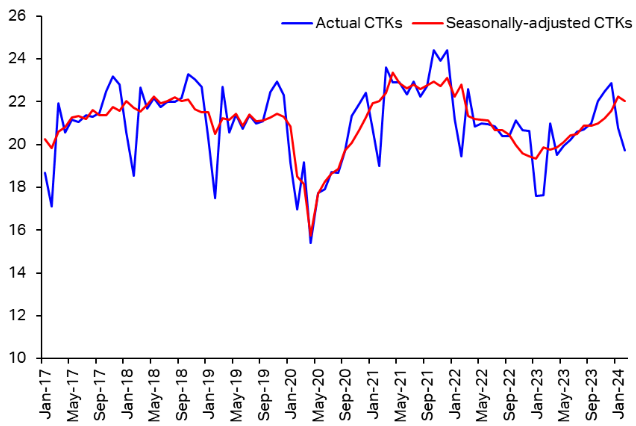
Air cargo growth continued to outpace macro indicators

- Industry-wide air cargo demand continued the momentum from previous months in February and registered the third consecutive month of double-digit year-on-year (YoY) growth in cargo tonne-kilometers (CTKs) with 11.9%.
- International CTKs expanded by 12.4% YoY globally, supported by all regions. The annual growth was championed by carriers from Africa and the Middle East.
- Industry-wide air cargo capacity, measured by available cargo tonne-kilometers (ACTK), increased by 13.4% YoY, largely due to the continued expansion of international passenger belly-hold capacity.
- The YoY expansion in traffic continued to outpace YoY growth in trade and production figures.
- Industry-wide air cargo yields declined by 1.5% compared to January, despite an average uptick in the jet fuel price and still with no discernible upward pressure from the Red Sea Shipping Crisis.

February brought the third consecutive month of double-digit YoY growth in air cargo demand

The air cargo industry registered a total of 19.7 billion CTKs in February, which represents an increase of 11.9% YoY **(Chart 1)**. This marks the third consecutive month of double-digit YoY growth after accounting for a seasonally reduced activity in Asia Pacific after the Lunar New Year mid-month. Notably, February 2024 was a leap year with one extra day compared to February 2023, which slightly exaggerates annual growth rates to the positive.

Chart 1 – Global CTKs (billion per month)

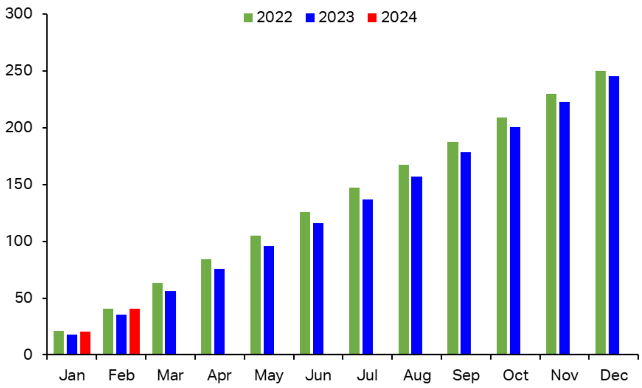


Sources: IATA Sustainability and Economics, IATA Monthly Statistics

Seasonally adjusted (SA) CTKs experienced a small decline of -1.0% month-on-month (MoM) in February but grew by 10.9% compared to the same month in 2023. The growing air cargo demand is a reflection of buoyant international traffic which benefits from booming e-commerce and possibly, though to a lesser extent, a recently increased interest in sea-air services because of the ongoing capacity constraints in maritime shipping, among other factors. Overall, air cargo demand appears set to continue the upward trend in SA CTKs that started early last year.

In year-to-date (YTD) terms, up to the month of February cumulative industry CTKs registered a total of 40.5 billion, up an impressive 15.0% from the 2023 value and only 0.3% below the heights experienced in early 2022 (**Chart 2**). With the falling monthly levels throughout most of 2022, it would be reasonable to expect the red bars in the chart to soon surpass the green ones as well.

Chart 2 – Year-to-date monthly CTKs (billion)



Sources: IATA Sustainability and Economics, IATA Monthly Statistics

Air cargo market in detail - February 2024

	World share[1]	February 2024 (% year-on-year)				February 2024 (% year-to-date)			
		CTK	ACTK	CLF (%-pt)	CLF (level)	CTK	ACTK	CLF (%-pt)	CLF (level)
TOTAL MARKET	*100.0%*	**11.9%**	**13.4%**	**-0.6%**	**45.1%**	**15.0%**	**13.9%**	**0.4%**	**45.4%**
International	*86.6%*	12.4%	16.0%	-1.6%	51.2%	15.9%	17.1%	0.2%	50.3%

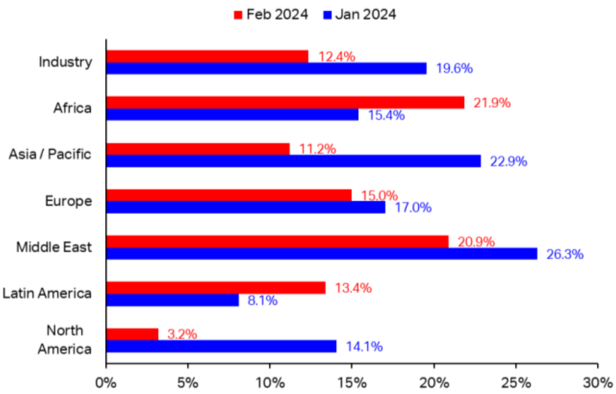
Note 1: % of industry CTKs in 2023

Positive annual growth in international air cargo traffic across the board, led by African and Middle Eastern carriers and expanding on European route areas

The solid 11.9% YoY growth in industry CTKs can be attributed to demand on international routes, which expanded by 12.4% YoY in February. And while the only two regions that experienced MoM expansions in February were Africa and Latin America, with 2.9% and 1.6%, respectively, the strong annual growth in the same month was supported by carriers from all regions of the world **(Chart 3)**.

In particular, airlines registered in Africa and the Middle East recorded the highest annual growth rates, with 21.9% and 20.9%, in that order. They were followed by carriers from Europe (15.0% YoY), Latin America (13.4%), and Asia Pacific (11.2%). Importantly, carriers from the Asia Pacific region experienced the strongest MoM contraction in CTKs last month, likely related to slowing activity after the Lunar New Year celebrations. The lowest annual growth in February was seen by North American airlines with 3.2% YoY, down from 14.1% in January.

Chart 3 – Growth in international CTKs (YoY) by airline region of registration



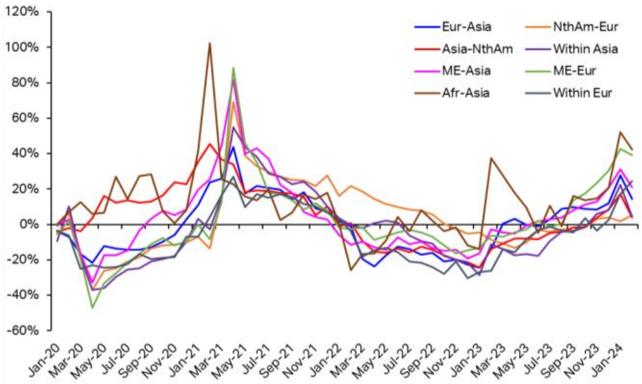
Sources: IATA Sustainability and Economics, IATA Monthly Statistics

As was the case in January, the strong 12.4% YoY growth in international CTKs in February was also supported by all route areas, but with slightly altered regional trends. The Africa–Asia and Middle East–Europe trade lanes experienced 42.3% and 39.3% YoY growth, respectively **(Chart 4)**. While these are outstanding annual growth rates, they came down from the peak values experienced in January. The Within Europe market followed after jumping to 24.5% YoY growth, the highest figure in almost three years. This February result was particularly impressive given that this market had been the last one (among major markets) to successfully recover to positive annual growth rates in 2023.

Growth rates on the Middle East–Asia and Europe–Asia routes dropped considerably to 21.0% and 14.3%, respectively. By contrast, the North America–Europe trade lane grew by 5.2% YoY in February, up from 1.9% seen in January. Within Asia and in the Asia–North America market, demand fell to 4.1% and 3.9% YoY, in that order. Both figures represent substantial drops compared to the previous month.

Overall, February brought renewed growth to European route areas. More precisely, the markets Within Europe and North America–Europe were the only two route areas that experienced an improvement in their annual growth rate in February compared to the previous month. Notably, the Middle East–Europe route also expanded MoM but closed with a slightly lower annual growth rate due to a pronounced base effect.

Chart 4 – International CTK growth (YoY) by route area

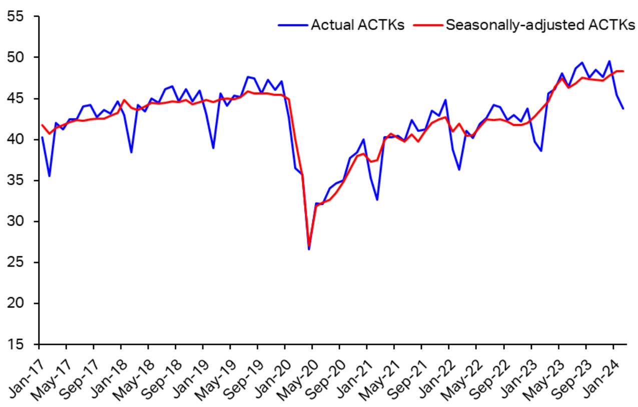


Sources: IATA Sustainability and Economics, IATA Monthly Statistics

Air cargo capacity expansion trend carried over to 2024, supported by returning passenger aircraft

Similar to the evolution on the demand side, air cargo capacity also continued on its downward path from the December high, with ACTKs falling to 43.8 billion last month **(Chart 5)**. Importantly, the figures remained 13.4% above 2023 levels and 20.6% above the 2022 benchmark. As such, the beginning of 2024 marks continued double-digit annual growth in ACTKs. In seasonally adjusted terms, industry-wide capacity increased by a marginal 0.01% MoM in February (and +10.5% YoY).

Chart 5 – Global ACTKs (billion per month)



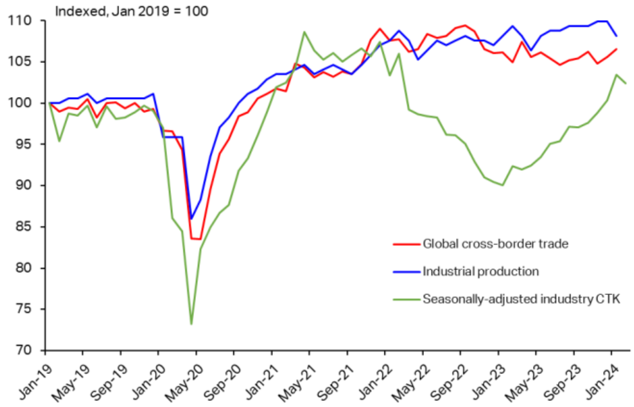
Sources: IATA Sustainability and Economics, IATA Monthly Statistics

The vast majority of the annual growth in industry ACTKs continues to come from the strong return in international passenger belly-hold capacity, which registered an outstanding 29.5% annual increase in February. By comparison, international cargo capacity for dedicated freighters rose by 3.2% YoY.

Air cargo demand growth continued to outpace the evolutions in goods trade and industrial production

January data for industrial production, a measure of the output generated by industrial sectors such as mining, manufacturing, and utilities, showed a 1.6% MoM drop from its year-end peak. Importantly, the levels achieved for the production statistics in January were virtually identical to the reading from the same month in 2023, mirroring the relatively stable evolution of this indicator over the past two years (**Chart 6**). By contrast, global cross-border trade recorded a 0.9% MoM uptick in January (+0.4% YoY), landing on the highest level in 10 months. However, trade levels continued to fall short of the post-pandemic heights achieved in 2022.

Chart 6 – Industrial production, global goods trade, and SA CTKs



Sources: IATA Sustainability and Economics, IATA Monthly Statistics, Netherlands CPB

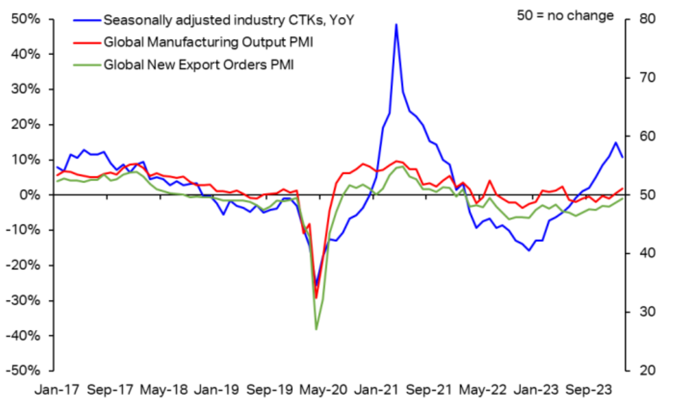
Overall, the relatively stable evolution of both merchandise trade and industrial production figures post-pandemic contrasts sharply with the momentum maintained over the past year by the global demand for air cargo, possibly supported by changing supply chains for e-commerce.

Manufacturing output saw the second expansion in a row, while pessimism persisted for new export orders

The Purchasing Managers' Index (PMI) gauges economic trends in manufacturing and services. A PMI above 50 suggests that more purchasing managers expect their business to grow compared to the previous month, while a figure below 50 indicates fewer managers with that outlook. Specifically, the manufacturing output and new export order PMIs are two leading indicators of global air cargo demand.

February continued to signal a slight contraction for new export orders, an indicator that measures the perceived well-being of international trade. In particular, the indicator stood at 49.4 (up from 48.8 in January). The contracting new export orders are in line with the global shift towards a more inward-looking economic environment coupled with tight financial conditions, as well as potential concerns regarding the Red Sea Shipping Crisis. It is notable, however, that purchasing managers' expectations regarding new export orders have been inching closer to the crucial 50-point benchmark over the past months **(Chart 7)**. In terms of the regional outlook, the US and PR China recently started registering some optimism, while expectations in Europe and Japan continued to indicate contraction.

Chart 7 – SA CTK growth, global manufacturing output and global new export orders PMIs



Sources: IATA Sustainability and Economics, IATA Monthly Statistics, S&P Global Markit

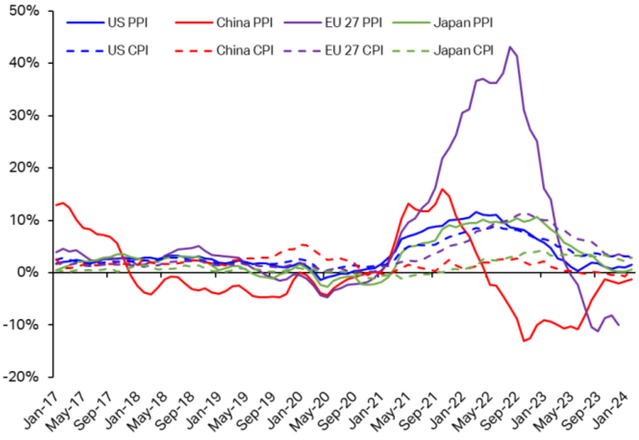
The global manufacturing output PMI rose to 51.2 points in February **(Chart 7)**, the second consecutive expansion in nine months. This is an encouraging signal and marks a positive outlook in the face of tight labor markets and supply chain disruptions that have been affecting the global manufacturing sector. The regional outlook for manufacturing output PMIs mirrors the one for the new export orders PMI. More precisely, the global expansion reflects positive overall expectations in the US and China, which are contrasted by continued pessimistic expectations in Europe and Japan.

The strong annual growth in industry CTKs over the past months contrasts with both the weakly contracting expectations for new export orders as well as the newly expanding manufacturing output PMI. In a nutshell, the industry is experiencing rapidly rising demand amid relatively soft demand drivers.

Amid fears of a looming economic slowdown in the region, February brought back positive YoY growth in China's consumer prices

Inflation as measured by the Consumer Price Index (CPI) continued to ease in February in the EU, with a reading of 2.8% YoY. At the same time, US consumer price inflation stayed roughly the same at 3.2% YoY (+0.06 ppt) and Japanese inflation increased by 0.6 ppt to 2.8% YoY. On the other hand, China reversed its previous negative inflation trend, which had persisted for a total of four consecutive months, with a reading of 0.7% YoY last month. This constitutes a sizeable increase from the -0.8% seen in January, which was the lowest inflation reading since the Global Financial Crisis in 2009. While this improvement in annual CPI growth can partially be attributed to a base effect, it also reflects a strong MoM increase in consumer prices. These figures represent a welcome development amid the ongoing fears of a looming economic slowdown in China **(Chart 8)**.

Chart 8 – Headline CPI and PPI inflation (YoY) in major economies



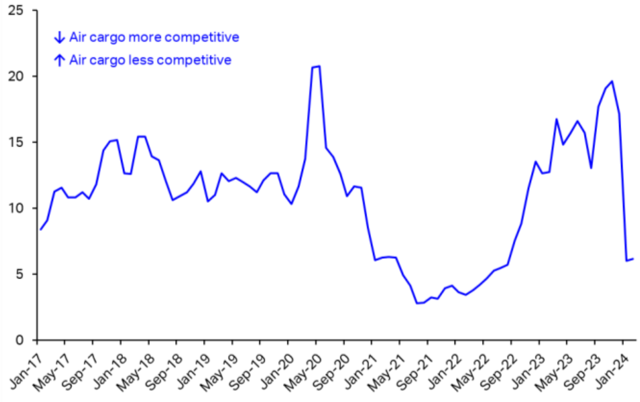
Sources: IATA Sustainability and Economics, Macrobond

Contrary to the CPI, the Producer Price Index (PPI) tracks changes in the prices that producers receive for their products. It can serve as a leading indicator for the CPI. In February, producer prices exhibited somewhat similar regional trends as the consumer side **(Chart 8)**. In particular, the US and Japan also registered an increase compared to the previous month, with the YoY growth in producer prices climbing to 1.6% and 0.6% YoY, respectively. The annual growth in China's PPI also rose compared to January but remained within negative territory at -1.3%, which adds some perspective to the positive developments observed on the consumer side. Both January and February readings of producer prices for the EU 27 countries are yet to be released. Meanwhile, the month of December maintained the major deflationary trend that began in May 2023, with a PPI reading of -10.0%. This latest reading reflects lower pressures from input costs such as energy as well as important base effects.

Global air cargo yields decreased further last month, with no visible impact by the capacity constraints in the Red Sea

Air cargo yields are closely connected to the developments surrounding cargo load factors, which dropped by a further 0.6 ppt in February to settle at 45.1%, likely influenced by slowing activity in the Asia Pacific region after the Lunar New Year. Specifically, global air cargo yields (including surcharges) also continued their recently initiated downward trajectory, registering a 1.5% MoM reduction (-18.3% YoY). This decline materialized despite a simultaneous rise in jet fuel prices, which increased by 3.1% MoM in February, closing at 112.1 USD per barrel with a continued, elevated jet fuel crack spread at around USD 28 per barrel. Similarly, the Red Sea Shipping Crisis and the related sharp decrease in relative air cargo rates over container shipping **(Chart 9)** continued to fail to produce significant upward pressure on the industry-average monthly yield for air cargo.

Chart 9: Ratio of chargeable weight rates for air cargo and container shipping (USD per kg)



Source: IATA Sustainability and Economics, Boeing, IATA CargoIS, Freightos Baltic Index

Air cargo market in detail - February 2024

	World share[1]	February 2024 (% year-on-year)				February 2024 (% year-to-date)			
		CTK	ACTK	CLF (%-pt)	CLF (level)	CTK	ACTK	CLF (%-pt)	CLF (level)
TOTAL MARKET	***100.0%***	**11.9%**	**13.4%**	**-0.6%**	**45.1%**	**15.0%**	**13.9%**	**0.4%**	**45.4%**
Africa	*2.0%*	22.0%	28.2%	-2.3%	45.1%	18.7%	23.3%	-1.7%	43.9%
Asia Pacific	*33.3%*	11.9%	23.1%	-4.3%	43.2%	18.1%	23.9%	-2.2%	44.0%
Europe	*21.4%*	14.6%	13.2%	0.7%	58.4%	15.6%	13.0%	1.3%	56.8%
Latin America	*2.8%*	13.7%	8.9%	1.6%	37.6%	10.7%	6.2%	1.4%	35.5%
Middle East	*13.5%*	20.9%	16.2%	1.8%	46.3%	23.6%	16.7%	2.5%	45.1%
North America	*26.9%*	4.2%	1.9%	0.9%	39.6%	6.7%	2.9%	1.5%	41.4%
International	***86.6%***	**12.4%**	**16.0%**	**-1.6%**	**51.2%**	**15.9%**	**17.1%**	**0.2%**	**50.3%**
Africa	*2.0%*	21.9%	28.0%	-2.3%	46.4%	18.6%	23.3%	-0.4%	45.2%
Asia Pacific	*29.8%*	11.2%	24.3%	-6.0%	50.9%	17.0%	26.0%	-0.4%	51.0%
Europe	*21.0%*	15.0%	13.8%	0.6%	60.4%	16.0%	13.6%	-0.1%	58.9%
Latin America	*2.4%*	13.4%	10.6%	1.0%	42.6%	10.7%	8.1%	2.6%	40.2%
Middle East	*13.4%*	20.9%	16.2%	1.8%	46.6%	23.6%	16.7%	0.4%	45.4%
North America	*17.9%*	3.2%	5.0%	-0.8%	48.1%	8.6%	8.5%	-1.1%	47.1%

Note 1: % of industry CTKs in 2023
Note 2: the total industry and regional growth rates are based on a constant sample of airlines combining reported data and estimates for missing observations. Airline traffic is allocated according to the region in which the carrier is registered; it should not be considered as regional traffic. Historical statistics are subject to revision.

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3 April 2024

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Country Analysis Brief: Congo Brazzaville (Republic of the Congo)

Last Updated: April 4, 2024
Next Update: April 2026

Independent Statistics and Analysis
U.S. Energy Information Administration

www.eia.gov
U.S. Department of Energy
Washington, DC 20585

April 4, 2024

Overview

Table 1. Congo Brazzaville's energy overview, 2021

	crude oil and other petroleum liquids	natural gas	coal	nuclear	hydro	renewables and other	total
Primary energy consumption (quad Btu)	0.02	0.02	0.00	0.00		0.01	0.05
Primary energy consumption (%)	50%	33%	0%	0%		17%	100%
Primary energy production (quad Btu)	0.57	0.02	0.00	0.00		0.01	0.59
Primary energy production (%)	96%	3%	0%	0%		1%	100%
Electricity generation (TWh)		3.12	0.00	0.00	0.90	0.00	4.02
Electricity generation (%)		78%	0%	0%	22%	0%	100%

Data source: US EIA International Energy Statistics database
Note: EIA aggregates hydroelectricity and renewables as "renewables and other" for primary energy production and consumption, and aggregates crude oil and other petroleum liquids and natural gas as "fossil fuels" for electricity generation

- The Republic of the Congo, or Congo Brazzaville, is a significant regional hydrocarbons producer in sub-Saharan Africa. Most of Congo Brazzaville's hydrocarbons production is located offshore. Congo Brazzaville holds sizable proved natural gas reserves, but only a small portion of the reserves is commercialized because of a lack of natural gas infrastructure. Congo Brazzaville exports most of its crude oil production, and revenues from crude oil exports play a large role in its economy, making its economy vulnerable to crude oil price volatility. In June 2018, Congo Brazzaville joined OPEC as a full member and is one of the six African nations in the organization.[1]

Figure 1. Map of Congo Brazzaville, as of 2024

Data source: U.S. Central Intelligence Agency, *CIA World Factbook*–Republic of the Congo

Petroleum and Other Liquids

- Congo Brazzaville held an estimated 1.8 billion barrels of proved crude oil reserves at the beginning of 2024, unchanged from the previous year.[2]
- Crude oil accounts for most of the total liquid fuels production in Congo Brazzaville; the country produces very small volumes of lease condensate and natural gas liquids. Congo Brazzaville produces and exports three main blends of crude oil: Djeno, N’Kossa, and Yombo (Table 2). The Djeno blend is a medium, sweet crude oil blend and is the primary blend produced and exported from Congo Brazzaville. N’Kossa is a very light, sweet crude oil blend produced in small volumes and is a blend of N’Kossa and Kitina crude oils. The Yombo blend is a heavy, sweet crude oil blend with a high viscosity level. Yombo’s crude oil properties are well suited for blending, and it is exported in small volumes primarily to destinations in the Asia-Pacific region, such as the Singapore-Malaysia fuel oil blending and storage hubs.[3]

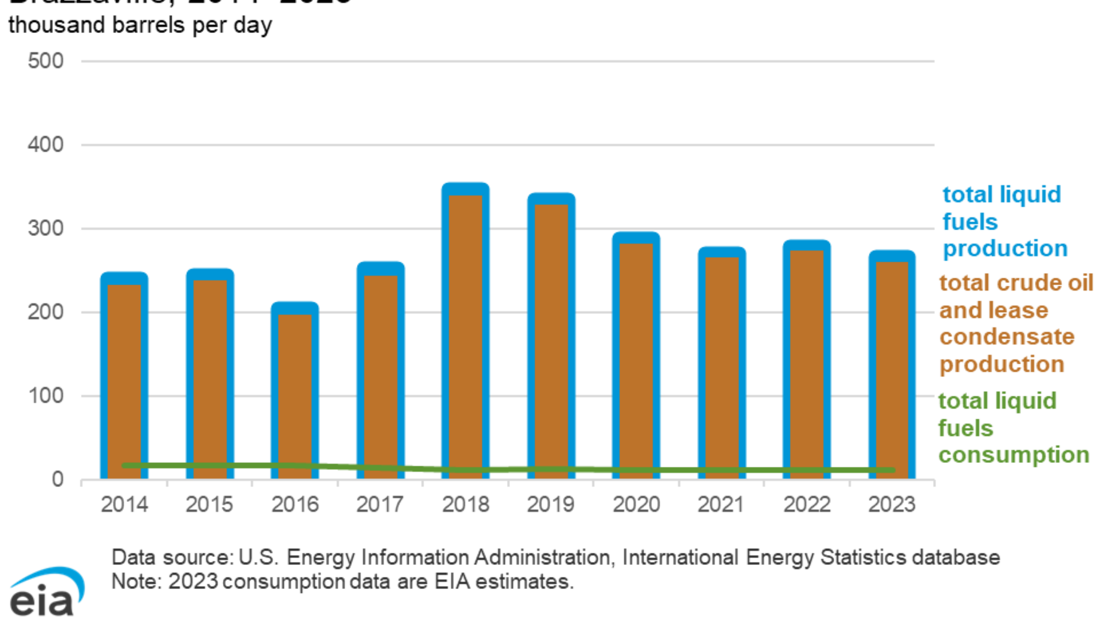
Table 2. Selected crude oil grades produced in Congo Brazzaville

Crude oil grade	API gravity number (degrees)	Sulfur content (percentage)
Djeno	26.4	0.54%
N'Kossa	42.4	0.04%
Yombo	16.7	0.34%

Data source: Vortexa, TotalEnergies company website

- Congo Brazzaville produced an average of about 273,000 barrels per day (b/d) of total liquid fuels from 2014 to 2023. Total liquid fuels production in Congo Brazzaville reversed its declining trend in the mid-2010s after a number of offshore fields in the N'Kossa Marine area were brought on line, enabling production to reach a decade-high of 347,000 b/d in 2018. Despite this recent growth, we expect the country's total liquid fuels production to decline as a result of overall field maturation and a slowdown in upstream development. The Congolese government wants to attract new investment in upstream development by making changes to its legal and regulatory framework, but these efforts are likely to be insufficient in attracting investor interest and reviving the country's liquid fuels production in the short term (Figure 1).[4]
- Rising production from Congo Brazzaville's offshore fields drove significant increases in total liquid fuels production in the latter half of the 2010s. The Moho Bilondo Phase 1b project in the northern part of the Moho Bilondo permit area began producing in 2015. The Moho Nord extension in the northern part of the same area started producing in 2017. TotalEnergies operates both developments. The Nene Marine offshore development in the Marine XII block and operated by Eni began producing in 2015. The Chevron-operated Lianzi offshore area is in a unitized offshore zone on the Congolese and Angolan boundaries. The Lianzi project is the country's first cross-border development and the first in Central Africa.[5]

Figure 1. Total annual liquid fuels production and consumption in Congo Brazzaville, 2014–2023



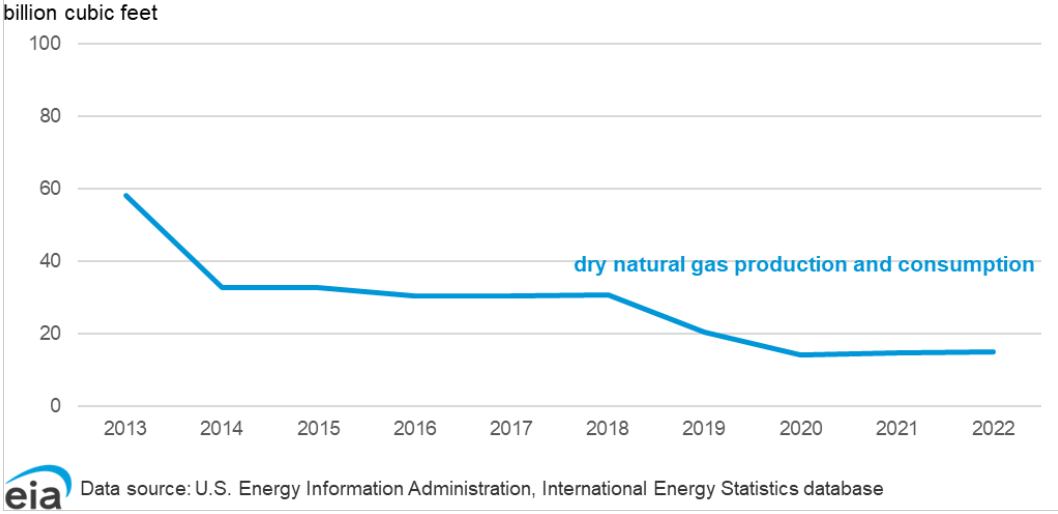
Data source: U.S. Energy Information Administration, International Energy Statistics database
Note: 2023 consumption data are EIA estimates.

- Congo Brazzaville has one operational refinery, the La Congolaise de Raffinage (CORAF) plant, in Pointe-Noire. The CORAF refinery has a nameplate capacity of 21,000 b/d, according to the *Oil & Gas Journal*. The Congolese government signed an agreement with Beijing Fortune Dingsheng Investment Company Limited to build a 110,000-b/d refinery in two phases at Pointe-Noire to meet increasing petroleum product demand in Congo Brazzaville and in the Central African subregion. The plant is reportedly still under construction and, according to *Offshore Technology*, is scheduled to begin operations in 2024.[6]

Natural Gas

- Congo Brazzaville held an estimated 10 trillion cubic feet (Tcf) of proved natural gas reserves at the beginning of 2024, unchanged from the previous year.[7]
- Dry natural gas production averaged about 28 billion cubic feet (Bcf) between 2013 and 2022. Congo Brazzaville uses all the natural gas it produces for domestic consumption (Figure 2).[8]

Figure 2. Total dry annual natural gas production and consumption in Congo Brazzaville, 2013–2022



Data source: U.S. Energy Information Administration, International Energy Statistics database

- Congo Brazzaville has not yet developed sufficient natural gas infrastructure for commercial export. So, a significant amount of Congo Brazzaville's natural gas that is produced is flared (or burned off) as a by-product of oil production or is reinjected into oil fields to aid crude oil recovery. According to the World Bank Group, Congo Brazzaville flared about 64 Bcf in 2022, accounting for significant volumes of Congo Brazzaville's production but far below the volumes flared by the top five flaring countries (Russia, Iraq, Iran, Algeria, and Venezuela) for that year.[9]

Coal

- Congo Brazzaville does not hold any coal reserves and so neither produces nor consumes any coal.

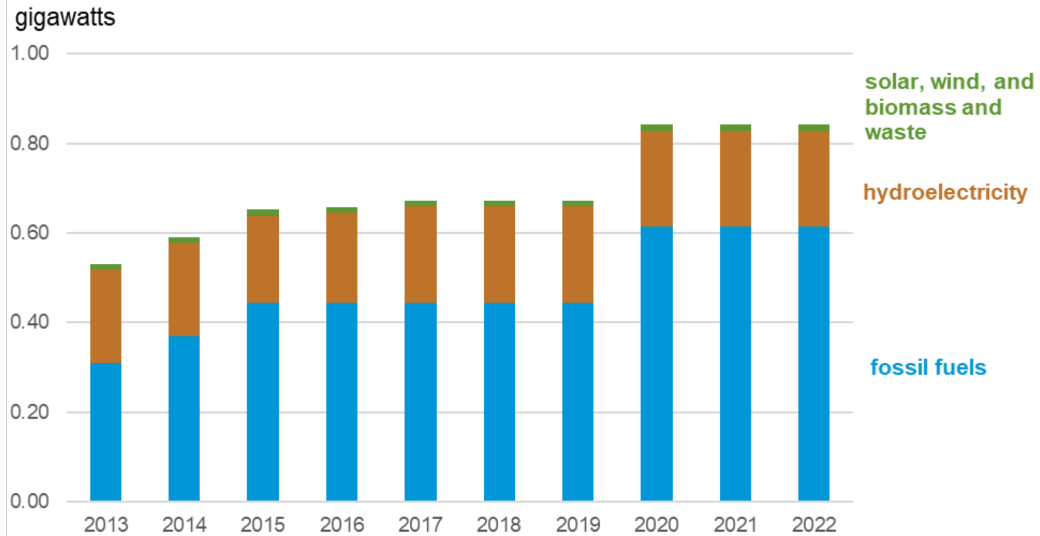
Electricity

- Total electricity capacity in Congo Brazzaville showed a modest increase of about 0.3 gigawatts (GW) from 2013 to 2022, with most of the increase coming from fossil fuel-derived sources.

Congo Brazzaville also had marginal growth in renewable sources such as solar. Electricity capacity derived from hydropower remained stable over the 10-year period (Figures 3 and 4).[10]

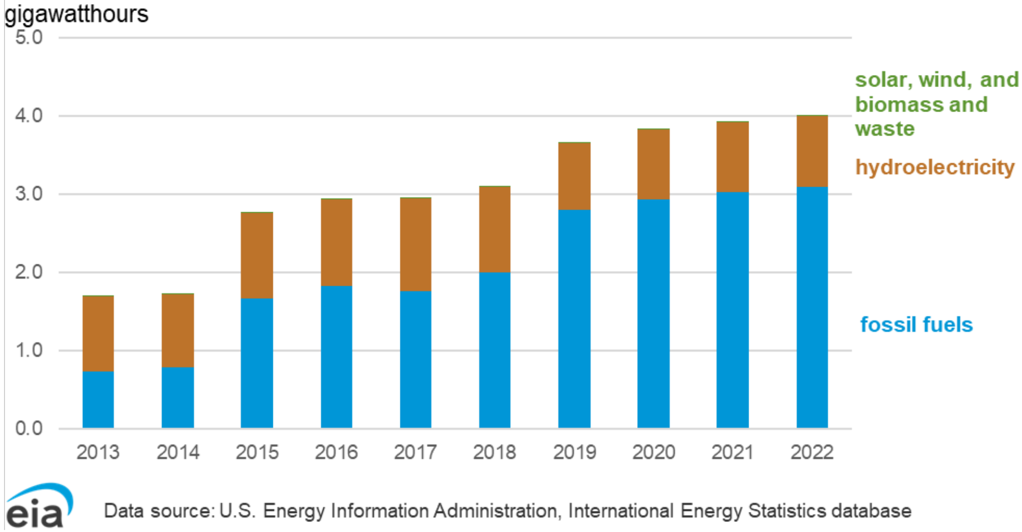
- The World Bank estimated that only 50% of the Congolese population had access to electricity in 2021, which is an increase of 10% from 2010. Access to electricity varies significantly between urban and rural populations. Access to electricity for urban populations in 2021 was 67%, up from 57% in 2010, while access for rural populations was 12% in the same year, a 1% increase from 2010. Providing reliable access to electricity for rural populations is a significant challenge because of underdeveloped infrastructure in the electric power sector.[11]
- Much of the growth in electricity capacity has come from natural gas projects. Installed capacity increased because of the construction of the Centrale Électrique du Djėno (CED) and Centrale Électrique du Congo (CEC) power plants in 2007 and 2010, respectively, and the capacity expansions that followed in subsequent years. Eni, the leading natural gas producer in Congo Brazzaville, constructed the two natural gas-fired power plants to reduce natural gas flaring and commercialize more of the associated natural gas produced at its oil fields. Eni also upgraded the connecting power transmission and distribution network to provide electricity access to the densely populated Pointe-Noire area. Both plants are fueled by associated natural gas from the M'Boundi and Marine XII fields.[12]

Figure 3. Congo Brazzaville's electricity capacity by fuel type, 2013–2022



Data source: U.S. Energy Information Administration, International Energy Statistics database

Figure 4. Congo Brazzaville's net electricity generation by fuel type, 2013–2022



Data source: U.S. Energy Information Administration, International Energy Statistics database

- Hydropower accounted for 25% Congo Brazzaville's total installed electricity capacity in 2021. As of early 2024, the country had three hydropower plants. Congo Brazzaville has significant hydropower potential, estimated at 3.9 GW, but only 5% of this power has been developed. Several hydropower projects are reportedly under consideration for development. The status of projects is unknown, and the projects appear to still be in early stages of development or deliberation (Table 3).[13]

Table 3. Hydroelectric power plants in Congo Brazzaville

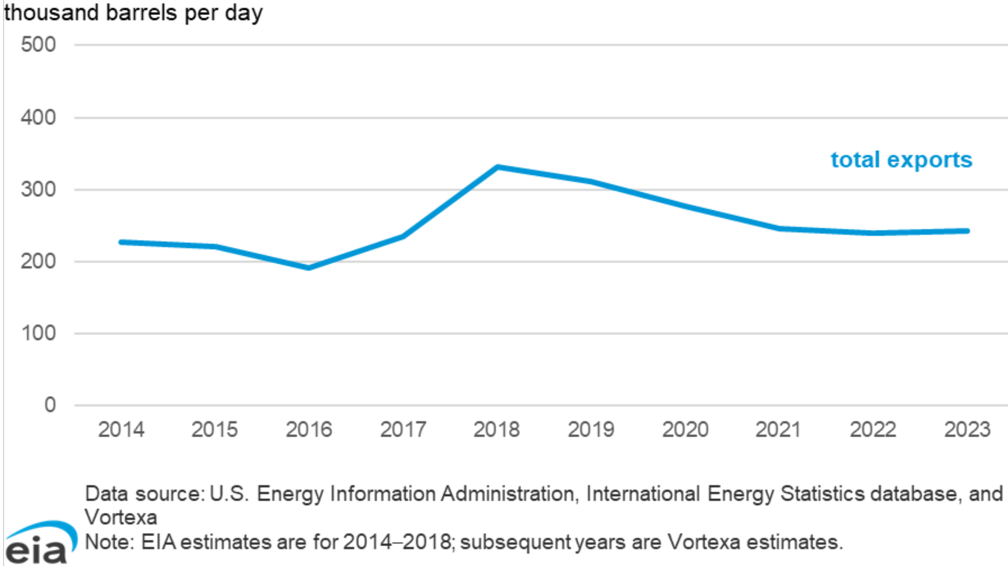
Facility name	Status	Nameplate capacity (megawatts)
Imboulou	Operating	120
Moukoukoulou	Operating	74
Djoue	Not operating	19
Chollet	Under development	600
Murala	Under development	150
Koeumbali	Under development	150
Loufoulakari	Under development	50

Data source: Andritz Group

Energy Trade

- Congo Brazzaville exports most of the crude oil it produces and keeps a small amount for its refinery for domestic consumption; the country does not import any crude oil. Congo Brazzaville exported an average of 252,000 b/d over the past decade (Figure 5).[14]

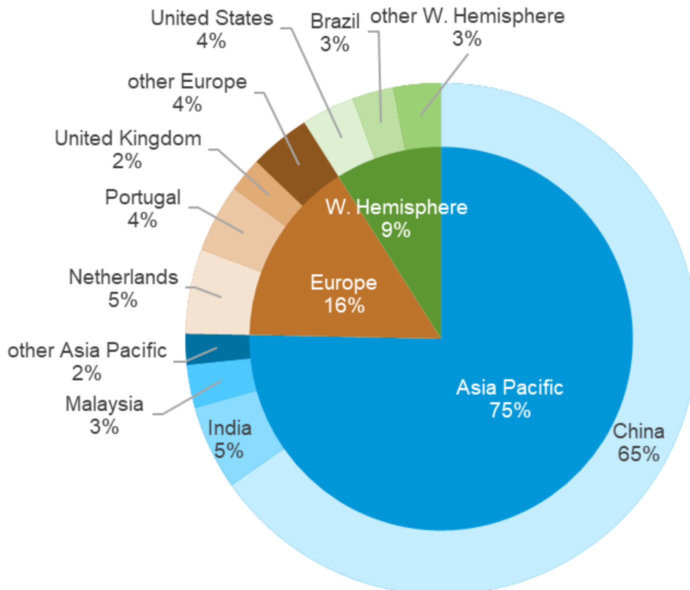
Figure 5. Congo Brazzaville's total annual exports of crude oil, 2014–2023



Data source: U.S. Energy Information Administration, International Energy Statistics database, and Vortexa
Note: EIA estimates are for 2014–2018; subsequent years are Vortexa estimates.

- In 2023, Congo Brazzaville exported about 242,000 b/d of crude oil and condensate, and about 75% of total exports went to the Asia-Pacific region. China was by far the top-importing country by volume, taking about 158,000 b/d of Congo Brazzaville's crude oil in 2023. India was the second-largest importer from the Asia-Pacific region by volume, taking about 13,000 b/d of imported crude oil from Congo Brazzaville. Europe and the Western Hemisphere (which is made up of North America, Central America, and South America as well as the Caribbean) as a region imported only 38,000 b/d and 22,000 b/d, respectively (Figure 6).[15]

Figure 6. Congo Brazzaville's crude oil exports by destination, 2023



Data source: Vortexa
Note: 2023 total export volumes exclude export volumes that have a destination territory labeled as *undetermined*.

- Congo Brazzaville imports and exports several different petroleum products. According to estimates of seaborne trade flows of petroleum products by Vortexa, Congo Brazzaville exported an average of about 8,000 b/d of petroleum products from 2020 to 2023, primarily naphtha, liquefied petroleum gases (LPG), and fuel oil. Congo Brazzaville imported about 4,000 b/d of petroleum products over the same time, and more than 70% of these imports were gasoline and diesel/gasoil (Figures 7 and 8).[16]

Figure 7. Congo Brazzaville's total annual petroleum product exports, 2020–2023
thousand barrels per day

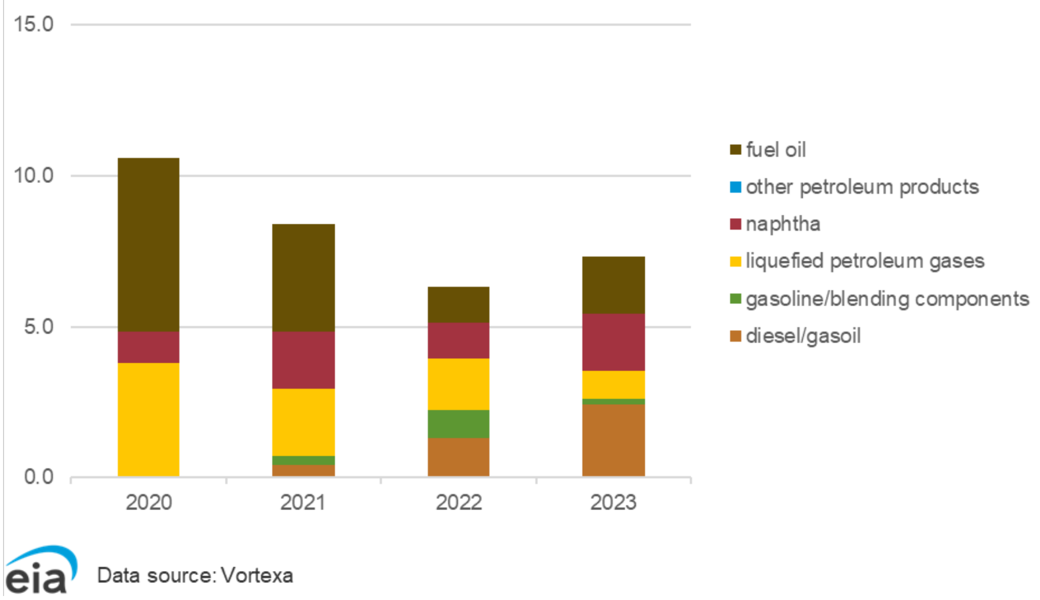
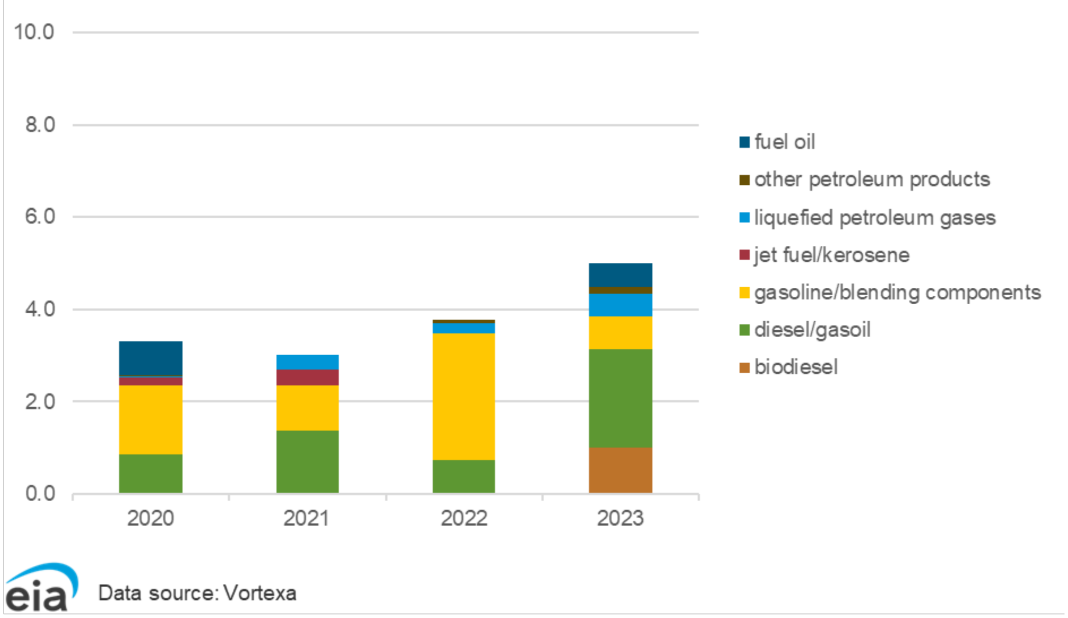


Figure 8. Congo Brazzaville's total annual petroleum product imports, 2020–2023
thousand barrels per day



- Congo Brazzaville does not export or import any natural gas; all of its dry natural gas production is consumed domestically, flared, or reinjected back into wells to enhance oil recovery.
- A liquefied natural gas (LNG) project is under development as of March 2024, which would enable the country to begin exporting natural gas not used for domestic consumption as well as monetize natural gas that would normally be flared or reinjected. The project is made up of two separate floating LNG (FLNG) facilities to be located offshore in the Marine XII block, from which

it will source its natural gas feedstock. The first facility, the Tango FLNG facility, is a fast-tracked project with a production capacity of 29 Bcf per year and is scheduled to begin operations by the end of 2024. The second, larger facility has a production capacity of about 115 Bcf per year and is currently under construction, but it is not scheduled to begin operations until 2025 (Table 4).[17]

Table 4. Congo Brazzaville's LNG terminals

Project name	Location	Status	Operator	Start date	Nameplate capacity (billion cubic feet per year)
Tango FLNG	Offshore Pointe-Noire	Under development	Eni	2024	29
Marine XII Block FLNG (Newbuild)	Offshore Pointe-Noire	Under development	Eni	2025	115
Total					**144**

Data source: *International Group of Liquefied Natural Gas Importers 2023 Annual Report*, Energy Intelligence, Fitch Solutions Country Risk & Industry Research
Note: FLNG=floating liquefied natural gas

- Congo Brazzaville neither imports coal for domestic consumption nor exports coal.

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EXTENDED RANGE FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2024

We anticipate that the 2024 Atlantic basin hurricane season will be extremely active. Current El Niño conditions are likely to transition to La Niña conditions this summer/fall, leading to hurricane-favorable wind shear conditions. Sea surface temperatures in the eastern and central Atlantic are currently at record warm levels and are anticipated to remain well above average for the upcoming hurricane season. A warmer-than-normal tropical Atlantic provides a more conducive dynamic and thermodynamic environment for hurricane formation and intensification. This forecast is of above-normal confidence for an early April outlook. We anticipate a well above-average probability for major hurricanes making landfall along the continental United States coastline and in the Caribbean. As with all hurricane seasons, coastal residents are reminded that it only takes one hurricane making landfall to make it an active season. Thorough preparations should be made every season, regardless of predicted activity.

(as of 4 April 2024)

By Philip J. Klotzbach[1], Michael M. Bell[2], Alexander J. DesRosiers[3], and Levi Silvers[4]
With Special Assistance from Carl J. Schreck III[5]
In Memory of William M. Gray[6]

Jennifer Dimas, Colorado State University media representative, is coordinating media inquiries in English and Spanish. She can be reached at 970-491-1543 or Jennifer.Dimas@colostate.edu

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2024

Forecast Parameter and 1991–2020 Average (in parentheses)	Issue Date 4 April 2024
Named Storms (NS) (14.4)	23
Named Storm Days (NSD) (69.4)	115
Hurricanes (H) (7.2)	11
Hurricane Days (HD) (27.0)	45
Major Hurricanes (MH) (3.2)	5
Major Hurricane Days (MHD) (7.4)	13
Accumulated Cyclone Energy (ACE) (123)	210
ACE West of 60°W (73)	125
Net Tropical Cyclone Activity (NTC) (135%)	220

PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING COASTAL AREAS:

1) Entire continental U.S. coastline – 62% (average from 1880–2020 is 43%)

2) U.S. East Coast Including Peninsula Florida (south and east of Cedar Key, Florida) – 34% (average from 1880–2020 is 21%)

3) Gulf Coast from the Florida Panhandle (west and north of Cedar Key, Florida) westward to Brownsville – 42% (average from 1880–2020 is 27%)

PROBABILITY FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE TRACKING THROUGH THE CARIBBEAN (10–20°N, 88–60°W)

1) 66% (average from 1880–2020 is 47%)

ABSTRACT

Information obtained through March indicates that the 2024 Atlantic hurricane season will have activity well above the 1991–2020 average. We estimate that 2024 will have 23 named storms (average is 14.4), 115 named storm days (average is 69.4), 11 hurricanes (average is 7.2), 45 hurricane days (average is 27.0), 5 major (Category 3-4-5) hurricanes (average is 3.2) and 13 major hurricane days (average is 7.4). The probability of U.S. and Caribbean major hurricane landfall is estimated to be well above its long-period average. We predict Atlantic basin Accumulated Cyclone Energy (ACE) and Net Tropical Cyclone (NTC) activity in 2024 to be approximately 170 percent of their long-term averages.

Coastal residents are reminded that it only takes one hurricane making landfall to make it an active season for them. Thorough preparations should be made for every season, regardless of how much activity is predicted.

This forecast is based on an extended-range early April statistical prediction scheme that was developed using ~40 years of past data. Analog predictors are utilized as well. We are also including statistical/dynamical models based off of 25–40 years of past data from the European Centre for Medium Range Weather Forecasts, the UK Met Office, the Japan Meteorological Agency and the Centro Euro-Mediterraneo sui Cambiamenti Climatici model as four additional forecast guidance tools. This model guidance is unanimously pointing towards a hyperactive season.

The tropical Pacific is currently characterized by El Niño conditions. These El Niño conditions are likely to transition to neutral ENSO conditions in the next few weeks and then to La Niña conditions by the peak of the Atlantic hurricane season. La Niña typically increases Atlantic hurricane activity through decreases in vertical wind shear. This year's sea surface temperatures in the eastern and central tropical Atlantic are much warmer than normal, also favoring an active Atlantic hurricane season via dynamic and thermodynamic conditions that are conducive to developing hurricanes.

The early April forecast is the earliest seasonal forecast issued by Colorado State University and has modest long-term skill when evaluated in hindcast mode. While the skill of this prediction is low, our confidence is higher than normal this year for an early April forecast given how hurricane-favorable the large-scale conditions appear to be. The skill of CSU's forecast updates increases as the peak of the Atlantic hurricane season approaches. We also present probabilities of exceedance for hurricanes and Accumulated Cyclone Energy to give interested readers a better idea of the uncertainty associated with these forecasts.

Why issue extended-range forecasts for seasonal hurricane activity?

We are frequently asked this question. Our answer is that it is possible to say something about the probability of the coming year's hurricane activity which is superior to climatology. The Atlantic basin has the largest year-to-year variability of any of the global tropical cyclone basins. People are curious to know how active the upcoming season is likely to be, particularly if you can show hindcast skill improvement over climatology for many past years.

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early April. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged with respect to the probability of an active or inactive hurricane season for the coming year. Our early April statistical and statistical/dynamical hybrid models show strong evidence on ~25–40 years of data that significant improvement over a climatological forecast can be attained. We would never issue a seasonal hurricane forecast unless we had models developed over a long hindcast period which showed skill. We also now include probabilities of exceedance to provide a visualization of the uncertainty associated with these predictions.

We issue these forecasts to satisfy the curiosity of the general public and to bring attention to the hurricane problem. There is a general interest in knowing what the odds are for an active or inactive season. One must remember that our forecasts are based on the premise that those global oceanic and atmospheric conditions which preceded comparatively active or inactive hurricane seasons in the past provide meaningful information about similar trends in future seasons.

It is also important that the reader appreciate that these seasonal forecasts are based on statistical and dynamical models which will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin these storms will strike. The probability of landfall for any one location along the coast is very low and reflects the fact that, in any one season, most U.S. coastal areas will not feel the effects of a hurricane no matter how active the individual season is.

Acknowledgment

These seasonal forecasts were developed by the late Dr. William Gray, who was lead author on these predictions for over 20 years and continued as a co-author until his death in 2016. In addition to pioneering seasonal Atlantic hurricane prediction, he conducted groundbreaking research on a wide variety of other topics including hurricane genesis, hurricane structure and cumulus convection. His investments in both time and energy to these forecasts cannot be acknowledged enough.

We are grateful for support from Ironshore Insurance, the Insurance Information Institute, Weatherboy and IAA. We acknowledge a grant from the G. Unger Vetlesen Foundation for additional financial support.

Colorado State University's seasonal hurricane forecasts have benefited greatly from a number of individuals that were former graduate students of William Gray. Among these former project members are Chris Landsea, John Knaff and Eric Blake. We also would like to thank Jhordanne Jones, recent Ph.D. graduate in Michael Bell's research group, for model development and forecast assistance over the past several years. Thanks also extend to several current members of Michael Bell's research group who have provided valuable comments and feedback throughout the forecast preparation process. These members include: Tyler Barbero, Delián Cólon Burgos, Jen DeHart, Nick Mesa, Angelie Nieves-Jimenez and Isaac Schluesche.

We thank Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre for providing data and insight on the statistical/dynamical models. We have also benefited from meteorological discussions with Louis-Philippe Caron, Dan Chavas, Jason Dunion, Brian McNoldy, Paul Roundy, Carl Schreck, Mike Ventrice and Peng Xian over the past few years.

DEFINITIONS AND ACRONYMS

Accumulated Cyclone Energy (ACE) - A measure of a named storm's potential for wind destruction defined as the sum of the square of a named storm's maximum wind speed (in 10^4 $knots^2$) for each 6-hour period of its existence. The 1991–2020 average value of this parameter is 123 for the Atlantic basin.

Atlantic Multi-Decadal Oscillation (AMO) – A mode of natural variability that occurs in the North Atlantic Ocean and evidencing itself in fluctuations in sea surface temperature and sea level pressure fields. The AMO is likely related to fluctuations in the strength of the oceanic thermohaline circulation. Although several definitions of the AMO are currently used in the literature, we define the AMO based on North Atlantic sea surface temperatures from 50–60°N, 50–10°W and sea level pressure from 0–50°N, 70–10°W.

Atlantic Basin – The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño – A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3–7 years on average.

ENSO Longitude Index (ELI) – An index defining ENSO that estimates the average longitude of deep convection associated with the Walker Circulation.

Hurricane (H) - A tropical cyclone with sustained low-level winds of 74 miles per hour (33 ms^{-1} or 64 knots) or greater.

Hurricane Day (HD) - A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or is estimated to have hurricane-force winds.

Indian Ocean Dipole (IOD) - An irregular oscillation of sea surface temperatures between the western and eastern tropical Indian Ocean. A positive phase of the IOD occurs when the western Indian Ocean is anomalously warm compared with the eastern Indian Ocean.

Madden Julian Oscillation (MJO) – A globally propagating mode of tropical atmospheric intra-seasonal variability. The wave tends to propagate eastward at approximately 5 ms^{-1}, circling the globe in roughly 30-60 days.

Major Hurricane (MH) - A hurricane which reaches a sustained low-level wind of at least 111 mph (96 knots or 50 ms^{-1}) at some point in its lifetime. This constitutes a category 3 or higher on the Saffir/Simpson scale.

Major Hurricane Day (MHD) - Four 6-hour periods during which a hurricane has an intensity of Saffir/Simpson category 3 or higher.

Named Storm (NS) - A hurricane, a tropical storm or a sub-tropical storm.

Named Storm Day (NSD) - As in HD but for four 6-hour periods during which a tropical or sub-tropical cyclone is observed (or is estimated) to have attained tropical storm-force winds.

Net Tropical Cyclone (NTC) Activity –Average seasonal percentage mean of NS, NSD, H, HD, MH, MHD. Gives overall indication of Atlantic basin seasonal hurricane activity. The 1991-2020 average value of this parameter is 135.

Oceanic Nino Index (ONI) – Three-month running mean of SST anomalies in the Nino 3.4 region (5°S–5°N, 170–120°W) based on centered 30-year base periods.

Saffir/Simpson Hurricane Wind Scale – A measurement scale ranging from 1 to 5 of hurricane wind intensity. One is a weak hurricane; whereas, five is the most intense hurricane.

Southern Oscillation Index (SOI) – A normalized measure of the surface pressure difference between Tahiti and Darwin. Low values typically indicate El Niño conditions.

Standard Deviation (SD) – A measure used to quantify the variation in a dataset.

Sea Surface Temperature Anomaly (SSTA) – Observed sea surface temperature differenced from a long-period average, typically 1991–2020.

Thermohaline Circulation (THC) – A large-scale circulation in the Atlantic Ocean that is driven by fluctuations in salinity and temperature. When the THC is stronger than normal, the AMO tends to be in its warm (or positive) phase, and more Atlantic hurricanes typically form.

Tropical Cyclone (TC) - A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms and other weaker rotating vortices.

Tropical Storm (TS) - A tropical cyclone with maximum sustained winds between 39 mph (18 ms^{-1} or 34 knots) and 73 mph (32 ms^{-1} or 63 knots).

Vertical Wind Shear – The difference in horizontal wind between 200 hPa (approximately 40000 feet or 12 km) and 850 hPa (approximately 5000 feet or 1.6 km).

1 knot = 1.15 miles per hour = 0.515 meters per second

1 Introduction

This is the 41st year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. Our research team has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. This year's April forecast is based on a statistical model as well as output from statistical/dynamical models from the European Centre for Medium-Range Weather Forecasts (ECMWF), the UK Met Office, the Japan Meteorological Agency (JMA) and the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC). These models show skill at predicting TC activity based on ~25–40 years of historical data. We also select analog seasons, based on currently-observed conditions as well as conditions that we anticipate for the peak of the Atlantic hurricane season. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by these analyses. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic basin TC activity and landfall probability. We believe that seasonal forecasts must be based on methods that show significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided that the atmosphere continues to behave in the future as it has in the past.

The best predictors do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain the portion of the variance of seasonal hurricane activity that are not associated with the other forecast variables. It is possible for an important hurricane forecast parameter to show little direct relationship to a predictand by itself but to have an important influence when included with a set of 2–3 other predictors.

2 April Forecast Methodology

2.1 April Statistical Forecast Scheme

Our current April statistical forecast model uses ECMWF Reanalysis 5 (ERA5; Hersbach et al. 2020). This model was developed on data from 1979–2020, was independently tested on data for 2021 and 2022 and was used for the real-time forecast for 2023. This model shows significant skill in cross-validated hindcasts of Accumulated Cyclone Energy (ACE) (r = 0.70) over the period from 1979–2023 (Figure 1). Cross-validation entails that for each year being forecast, the equation is developed on all other years in the hindcast but excluding the year being forecast. So a forecast for 1979 would be based on a hindcast equation developed on 1980–2020, a forecast for 1980 would be based on a hindcast equation developed on 1979 and 1981–2020, etc.

Figure 2 displays the locations of each predictor, while Table 1 displays the individual linear correlations between each predictor and ACE over the 1979–2023 hindcast/forecast period. All predictors correlate significantly at the 5% level using a two-tailed Student's t-test, and each year is assumed to represent an individual degree of freedom. Table 2 displays the 2024 observed values for each of the three predictors in the statistical forecast scheme. Table 3 displays the statistical model output for the 2024 hurricane season. The two SST predictors call for an extremely active Atlantic hurricane season, while the 200 hPa zonal wind predictor calls for a near-average season. The three predictors in combination call for an extremely active season.

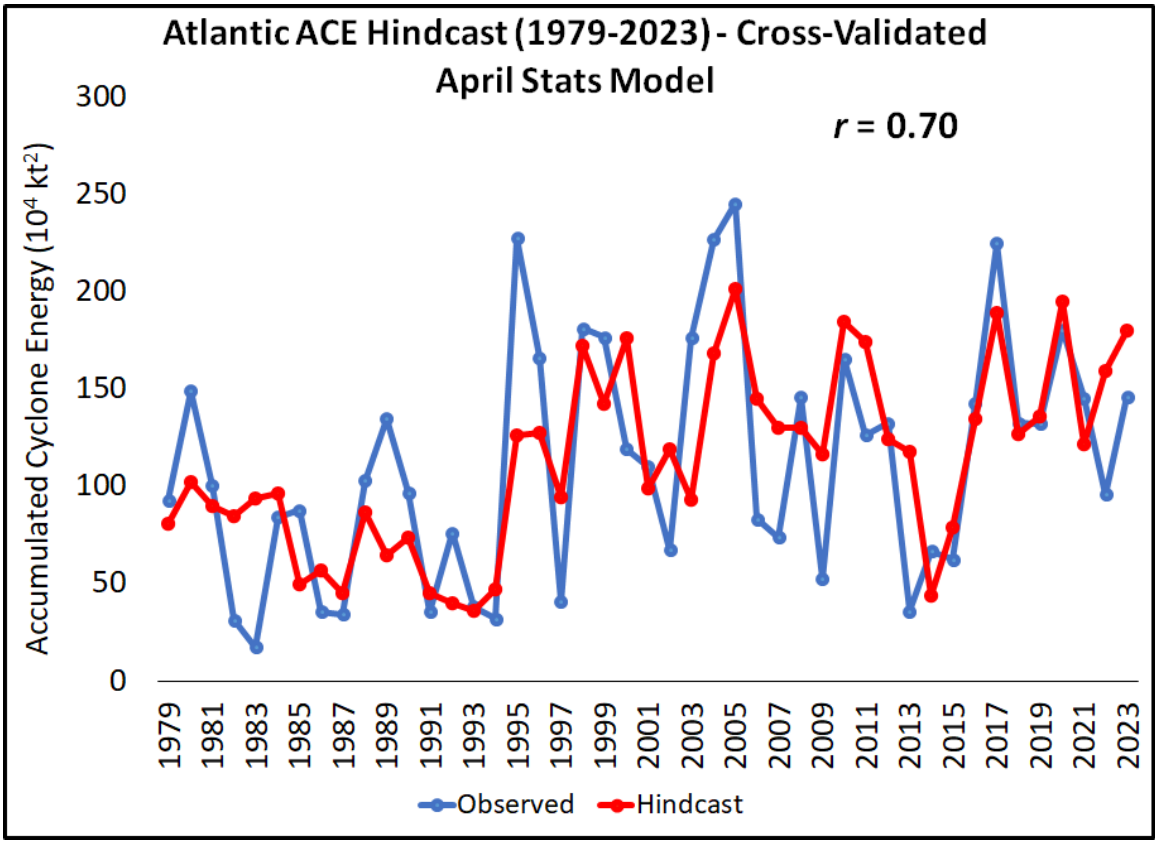


Figure 1: Observed versus early April cross-validated hindcast values of ACE for the statistical model from 1979–2023.

Statistical Model Predictors

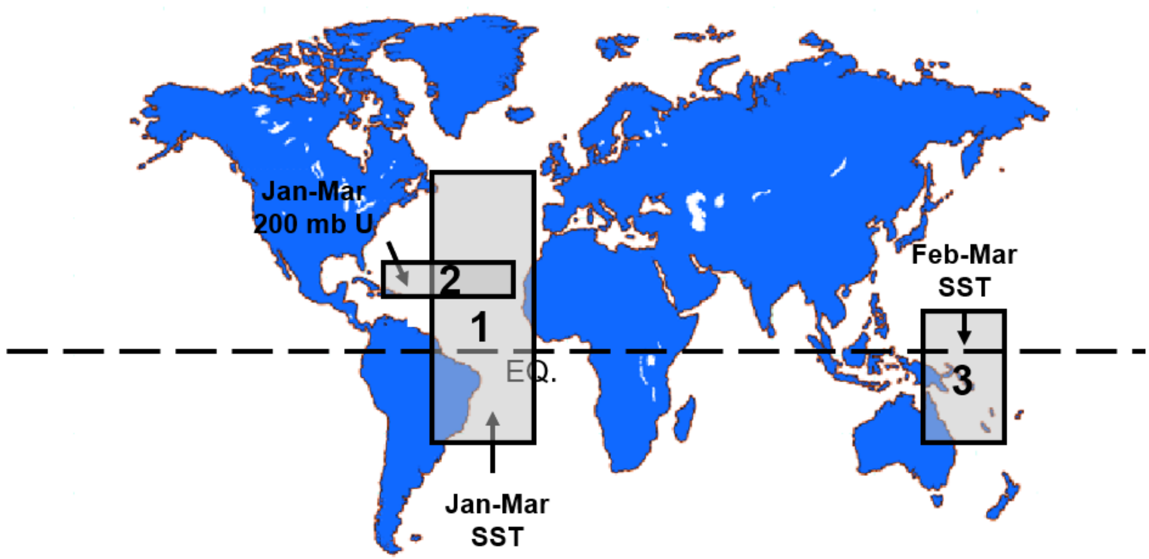


Figure 2: Location of predictors for our early April extended-range statistical prediction for the 2024 hurricane season.

Table 1: Linear correlation between early April predictors and ACE over the period from 1979–2023.

Predictor	Correlation w/ ACE
1) January–March SST (30°S–50°N, 40°W–10°W) (+)	0.56
2) January–March 200 hPa U (17.5°N–27.5°N, 60°W–20°W) (+)	0.43
3) February–March SST (30°S–15°N, 140°E–170°E) (+)	0.52

Table 2: Listing of early April 2024 predictors for the 2024 hurricane season. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity. SD stands for standard deviation.

Predictor	2024 Forecast Value	Impact on 2024 TC Activity
1) January–March SST (30°S–50°N, 40°W–10°W) (+)	+4.6 SD	Strongly Enhance
2) January–March 200 hPa U (17.5°N–27.5°N, 60°W–20°W) (+)	-0.1 SD	Neutral
3) February-March SST (30°S–15°N, 140°E–170°E) (+)	+1.9 SD	Enhance

Table 3: Statistical model output for the 2024 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Forecast	Final Forecast
Named Storms (NS) (14.4)	24.9	23
Named Storm Days (NSD) (69.4)	130.8	115
Hurricanes (H) (7.2)	13.6	11
Hurricane Days (HD) (27.0)	60.4	45
Major Hurricanes (MH) (3.2)	7.0	5
Major Hurricane Days (MHD) (7.4)	19.5	13
Accumulated Cyclone Energy (ACE) (123)	269	210
Net Tropical Cyclone Activity (NTC) (135%)	283	220

The locations and brief descriptions of the predictors for our early April statistical forecast are now discussed. It should be noted that all predictors correlate positively with physical features during August through October that are known to be favorable for elevated levels of hurricane activity. These factors are all generally related to August–October vertical wind shear in the Atlantic Main Development Region (MDR) from 10–20°N, 85–20°W as shown in Figure 3.

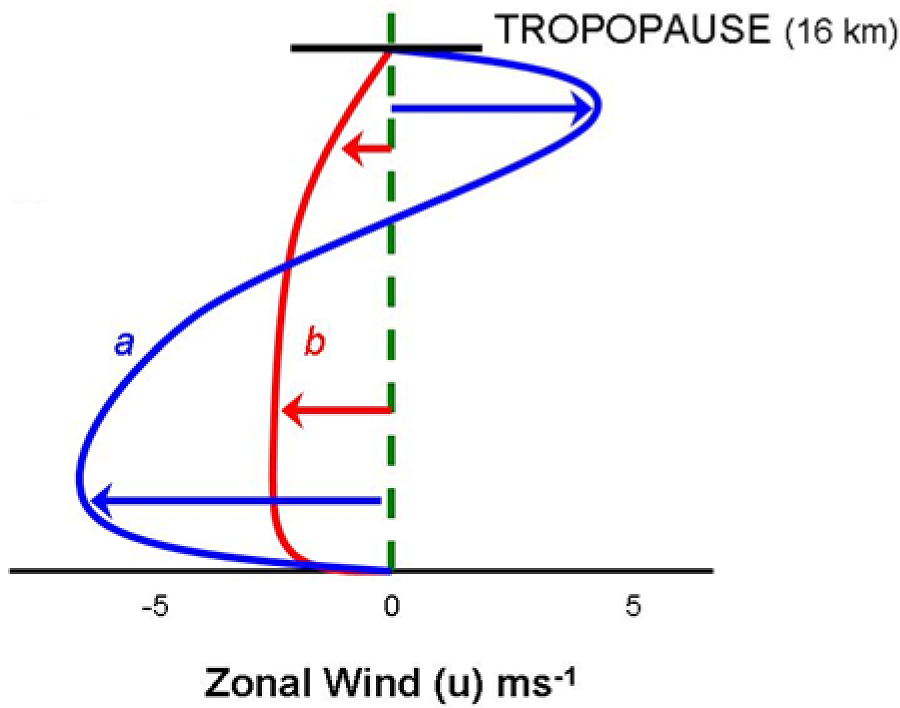


Figure 3: Vertical wind profile in the MDR typically associated with (a) inactive Atlantic basin hurricane seasons and (b) active Atlantic basin hurricane seasons. Note that (b) has reduced levels of vertical wind shear.

For each of these predictors, we display a four-panel figure showing linear correlations between values of each predictor and August–October values of SST, sea level pressure (SLP), 200 hPa zonal wind, and 850 hPa zonal wind, respectively, during 1979–2022. In general, higher values of tropical Atlantic SSTs, lower values of tropical Atlantic SLP, anomalous tropical Atlantic westerlies at 850 hPa, and anomalous tropical Atlantic easterlies at 200 hPa are associated with active Atlantic basin hurricane seasons. All correlations are displayed using ERA5.

<u>Predictor 1. January–March SST in the tropical and subtropical eastern Atlantic (+)</u>

(30°S–50°N, 40°W–10°W)

Warmer-than-normal SSTs in the tropical and subtropical Atlantic during the January–March time period are associated with a weaker-than-normal subtropical high and reduced trade wind strength during the boreal spring (Knaff 1997). Anomalously warm SSTs in January–March are correlated with weaker trade winds and weaker upper tropospheric westerly winds, lower-than-normal sea level pressures, and above-normal SSTs in the tropical Atlantic during the following August–October period (Figure 4). All three of these August–October features are commonly associated with active Atlantic basin hurricane seasons, through reductions in vertical wind shear, increased vertical instability and increased mid-tropospheric moisture, respectively. Predictor 1 correlates quite strongly (*r* =0.56) with ACE from 1979–2022. Predictor 1 also strongly correlates (*r* = 0.56) with August–October values of the SST component of the Atlantic Meridional Mode (AMM) (Kossin and Vimont 2007) from 1979–2022. The AMM has been shown to impact Atlantic hurricane activity through alterations in the position and intensity of the Atlantic Inter-Tropical Convergence Zone (ITCZ). Changes in the Atlantic ITCZ bring about changes in tropical Atlantic vertical and horizontal wind shear patterns and in tropical Atlantic SST patterns.

<u>Predictor 2. January–March 200 hPa U in the subtropical North Atlantic (+)</u>

(17.5°N–27.5°N, 60°W–20°W)

Anomalously strong winds at upper-levels in the subtropical North Atlantic are associated with anomalously low pressure in the tropical and subtropical Atlantic during January–March. Stronger-than-normal westerly winds at upper levels in the subtropics are also associated with reduced anticyclonic wavebreaking (and associated reduced vertical wind shear) during the peak of the Atlantic hurricane season (Jones et al. 2022). As has been shown in prior work (Knaff 1997), when the Azores High is weaker than normal, Atlantic trade winds are also weaker than normal. These weaker trades inhibit ocean mixing and upwelling, thereby causing anomalous warming of tropical Atlantic SSTs. These warmer SSTs are then associated with lower-than-normal sea level pressures which can create a self-enhancing feedback that relates to lower pressure, weaker trades and warmer SSTs during the hurricane season (Figure 5) (Knaff 1998). All three of these factors are associated with active hurricane seasons. This predictor is also negatively correlated with tropical central Pacific SSTs during August–October, indicating that La Niña-like conditions are favored during the boreal summer when anomalously strong upper-level winds predominate over the Atlantic during January–March.

<u>Predictor 3. February–March SST in the western tropical/subtropical Pacific (+)</u>

(30°S–15°N, 140°E–170°E)

Anomalous warmth in the western tropical/subtropical Pacific is associated with lower pressure in the western tropical Pacific and higher pressure in the eastern tropical Pacific, thereby driving stronger trade winds across the tropical Pacific that inhibit El Niño development. The development of anomalously high pressure in the eastern tropical Pacific then drives anomalously weak trade winds in the tropical Atlantic, feeding back into both reduced shear and anomalously warm SSTs in the tropical Atlantic by the peak of the Atlantic hurricane season (August–October) (Figure 6).

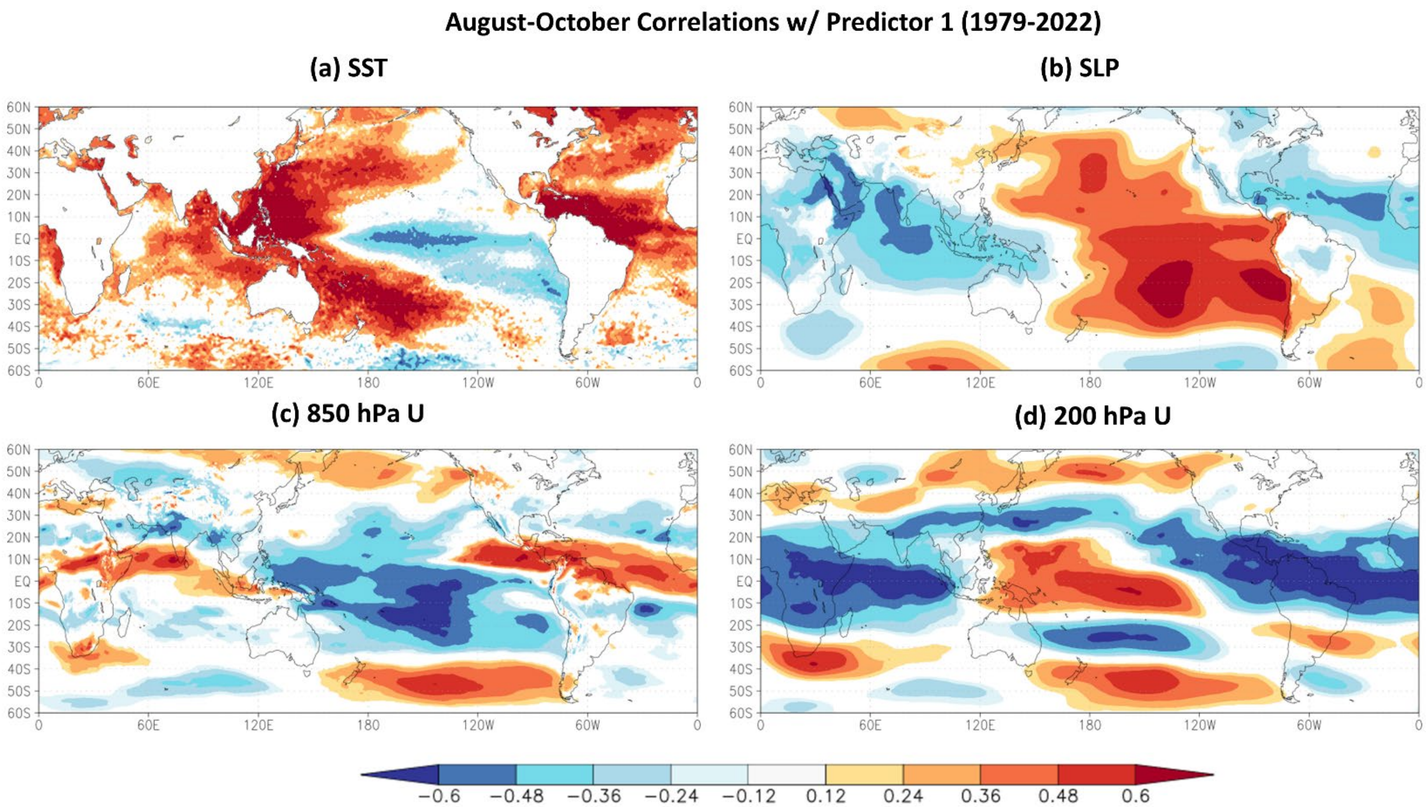


Figure 4: Rank correlations between January–March SST in the tropical and subtropical Atlantic (Predictor 1) and (panel a) August–October sea surface temperature, (panel b) August–October sea level pressure, (panel c) August–October 850 hPa zonal wind and (panel d) August–October 200 hPa zonal wind. All four of these parameter deviations in the tropical Atlantic are known to be favorable for enhanced hurricane activity.

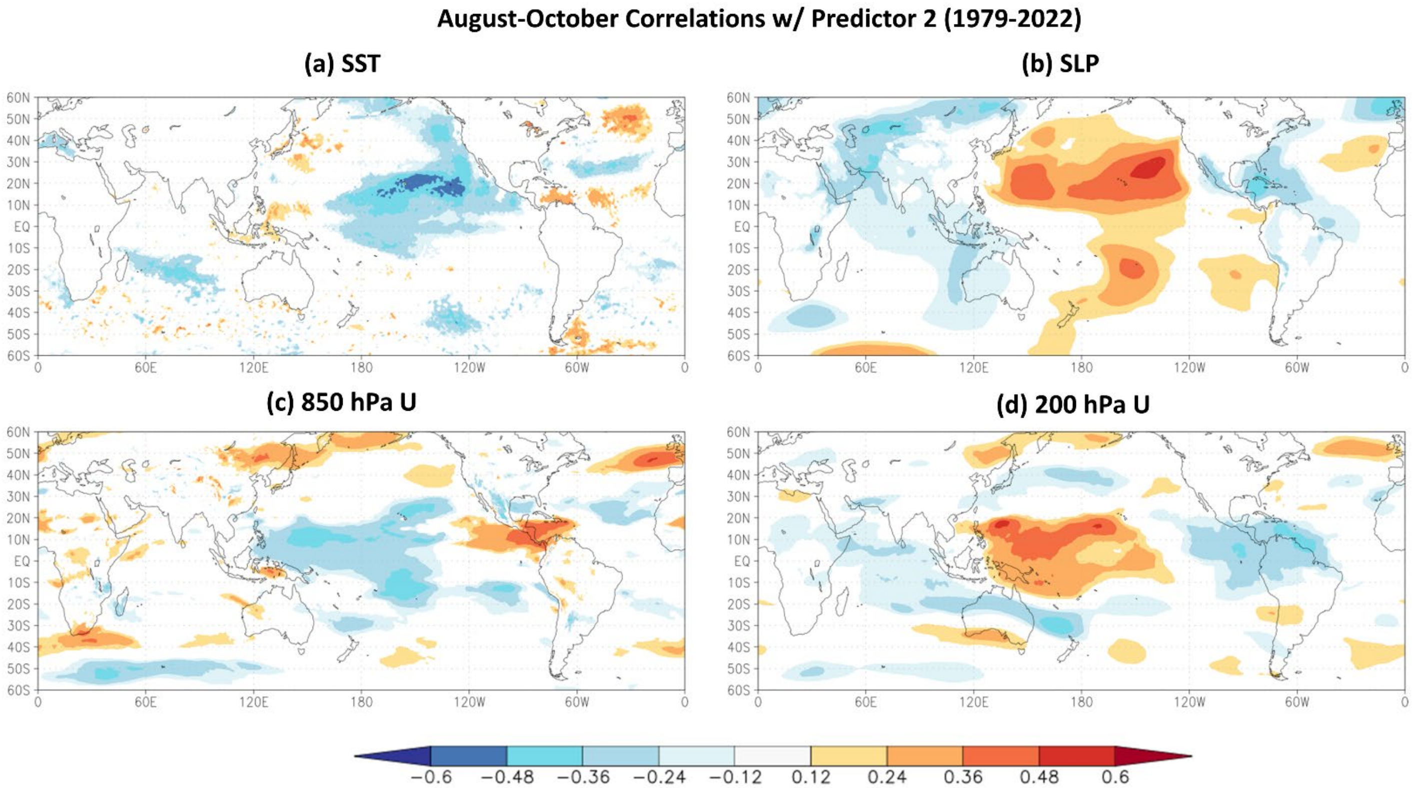


Figure 5: As in Figure 4 but for January–March 200 hPa zonal wind in the subtropical North Atlantic.

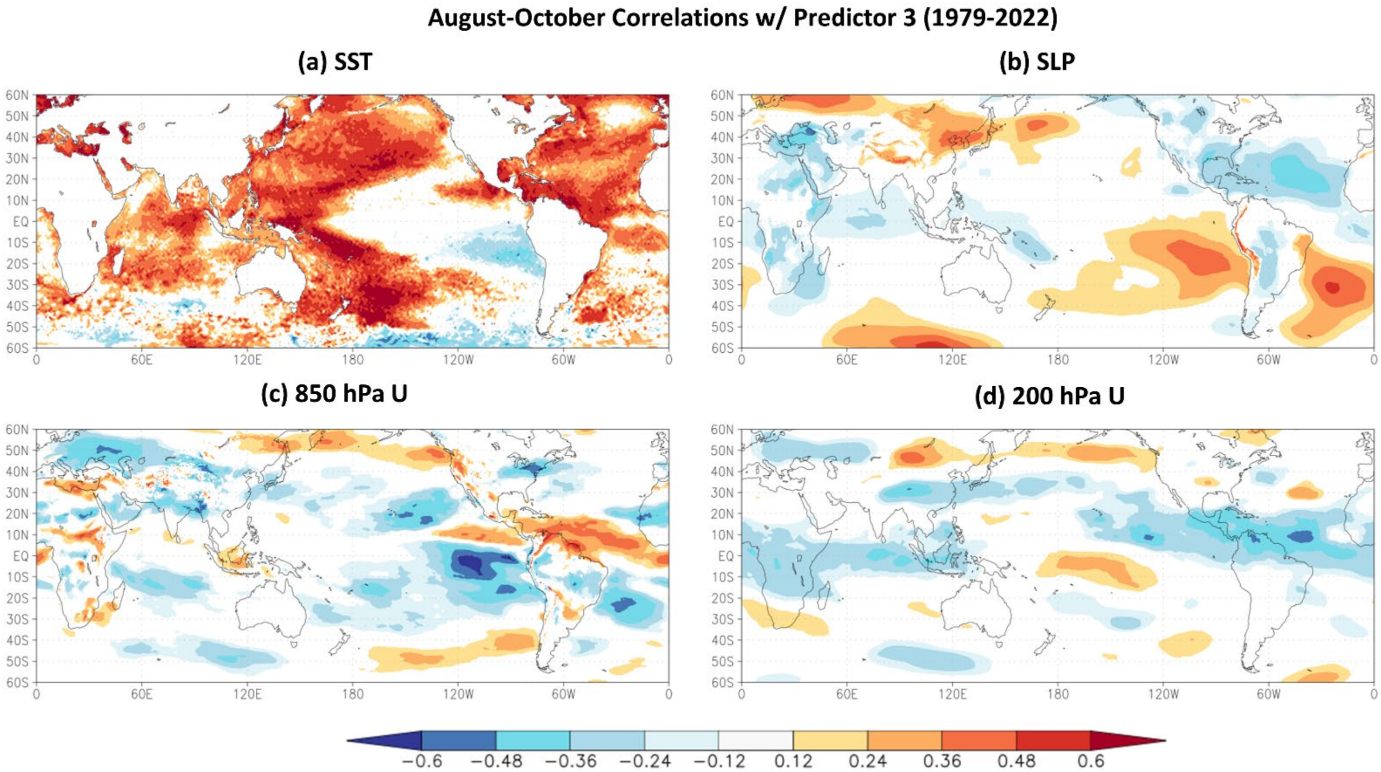


Figure 6: As in Figure 4 but for February–March SST in the western tropical/subtropical Pacific.

2.2 April Statistical/Dynamical Forecast Schemes

We developed a statistical/dynamical hybrid forecast model scheme that we used for the first time in 2019. This model, developed in partnership with Louis-Philippe Caron and the data team at the Barcelona Supercomputing Centre, originally used output from the ECMWF SEAS5 model to forecast the input to our early August statistical forecast model. We now use four different models, namely, ECMWF, UK Met, JMA and CMCC, to forecast August SSTs in the eastern/central equatorial Pacific and in the eastern/central North Atlantic. We then use the forecasts of these individual parameters to forecast ACE for the 2024 season. All other predictands (e.g., named storms, major hurricanes) are calculated based on their historical relationships with ACE. These model forecasts extend out six months, which is why all forecasts here examine August data.

a) ECMWF Statistical/Dynamical Model Forecast

Figure 7 displays the locations of the two forecast parameters, while Table 4 displays ECMWF's forecasts of these parameters for 2024 from a 1 March initialization date. The ensemble average of the ECMWF model is predicting the warmest eastern/central North Atlantic on record (since 1981) and a cool neutral/weak La Niña. This combination yields the highest predicted ACE on record for this forecast scheme.

Figure 8 displays cross-validated hindcasts for ECMWF forecasts of ACE from 1981–2023, while Table 5 presents the forecast from ECMWF for the 2024 Atlantic hurricane season.

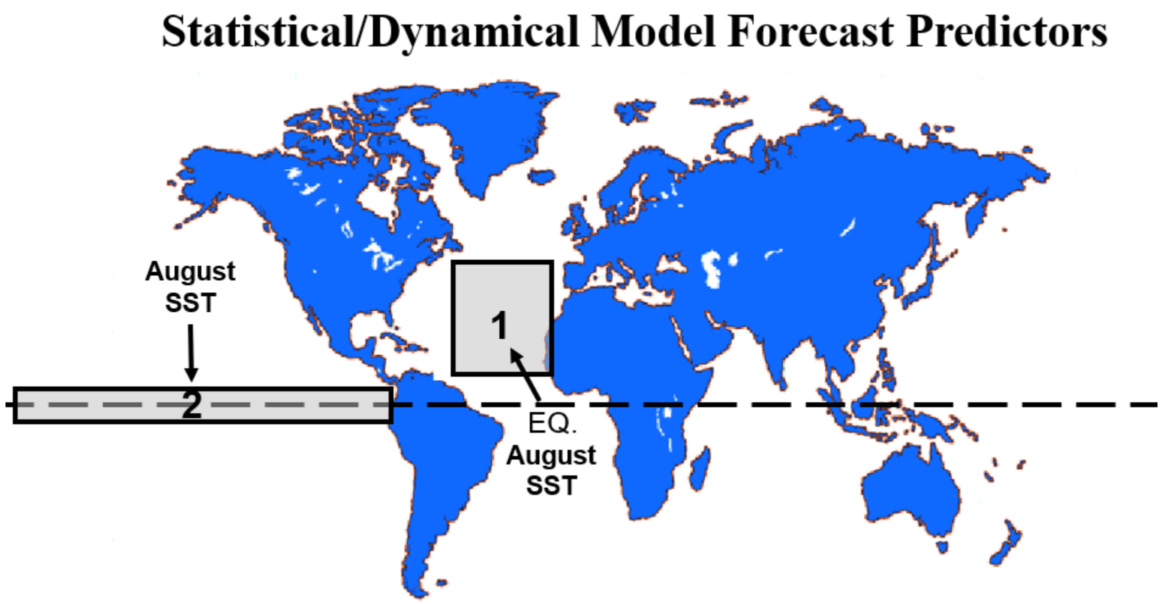


Figure 7: Location of predictors for our early April statistical/dynamical extended-range statistical prediction for the 2024 hurricane season. This forecast uses dynamical model predictions from ECMWF, the UK Met Office, JMA and CMCC to predict August SSTs in the two boxes displayed and then uses those predictors to forecast ACE.

Table 4: Listing of predictions of August large-scale conditions from ECMWF model output, initialized on 1 March. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2024 Forecast	Effect on 2024 Hurricane Season
1) ECMWF Prediction of August SST (10–45°N, 60–20°W) (+)	+3.2 SD	Strongly Enhance
2) ECMWF Prediction of August SST (5°S–5°N, 180–90°W) (-)	-0.6 SD	Enhance

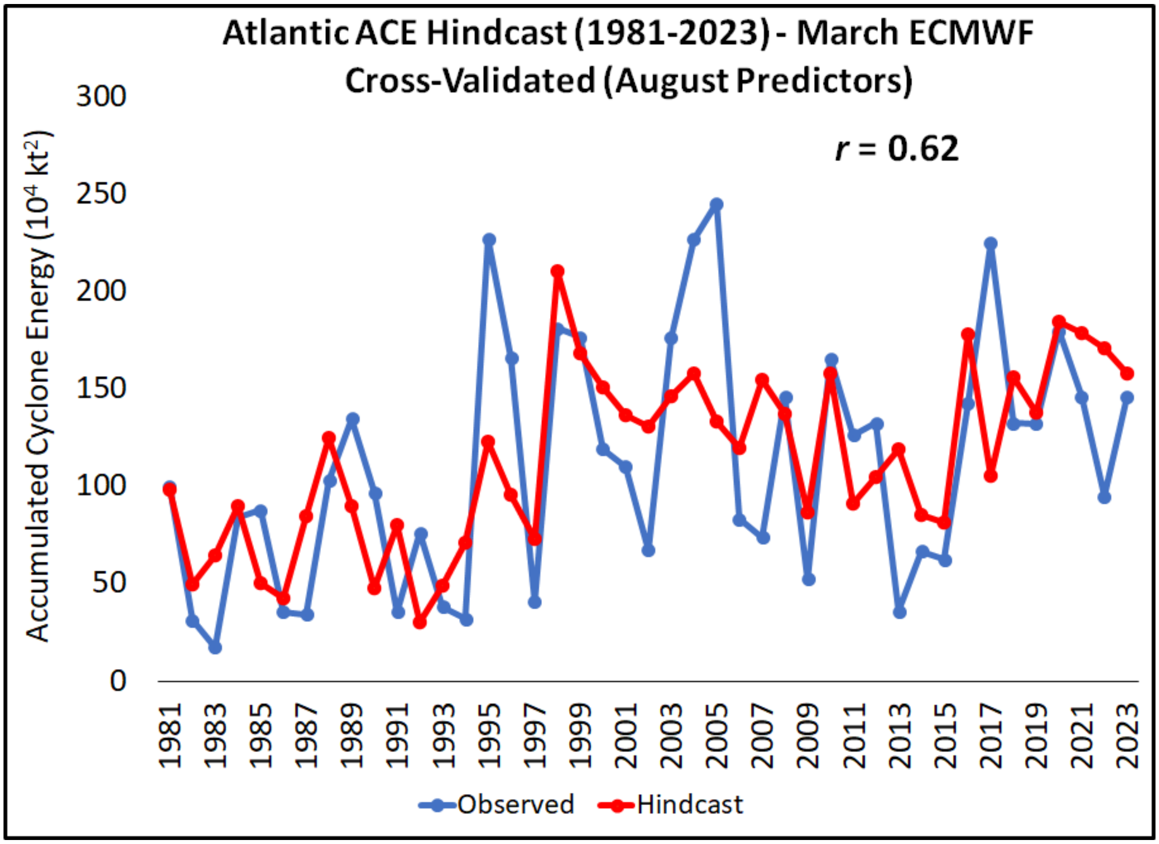


Figure 8: Observed versus cross-validated statistical/dynamical hindcast values of ACE for 1981–2023 from ECMWF.

Table 5: Statistical/dynamical model output from ECMWF for the 2024 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	ECMWF Hybrid Forecast	Final Forecast
Named Storms (14.4)	22.7	23
Named Storm Days (69.4)	115.7	115
Hurricanes (7.2)	12.0	11
Hurricane Days (27.0)	52.2	45
Major Hurricanes (3.2)	6.1	5
Major Hurricane Days (7.4)	16.5	13
Accumulated Cyclone Energy Index (123)	233	210
Net Tropical Cyclone Activity (135%)	247	220

b) UK Met Office Statistical/Dynamical Model Forecast

Table 6 displays the UK Met Office forecasts of the August parameters for 2024 from a 1 March initialization date. The ensemble average from the UK Met Office dynamical model (GloSea6) is calling for a warmer central/eastern North Atlantic than in any year in the hindcast period from 1993–2016 and a robust La Niña. Figure 9 displays hindcasts for the UK Met Office of ACE from 1993–2016, while Table 7 presents the forecast from the statistical/dynamical model guidance based off GloSea6 for the 2024 Atlantic hurricane season.

Table 6: Listing of predictions of August large-scale conditions from UK Met model output, initialized on 1 March. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2024 Forecast	Effect on 2024 Hurricane Season
1) UK Met Prediction of August SST (10–45°N, 60–20°W) (+)	+4.2 SD	Strongly Enhance
2) UK Met Prediction of August SST (5°S–5°N, 180–90°W) (-)	-1.7 SD	Enhance

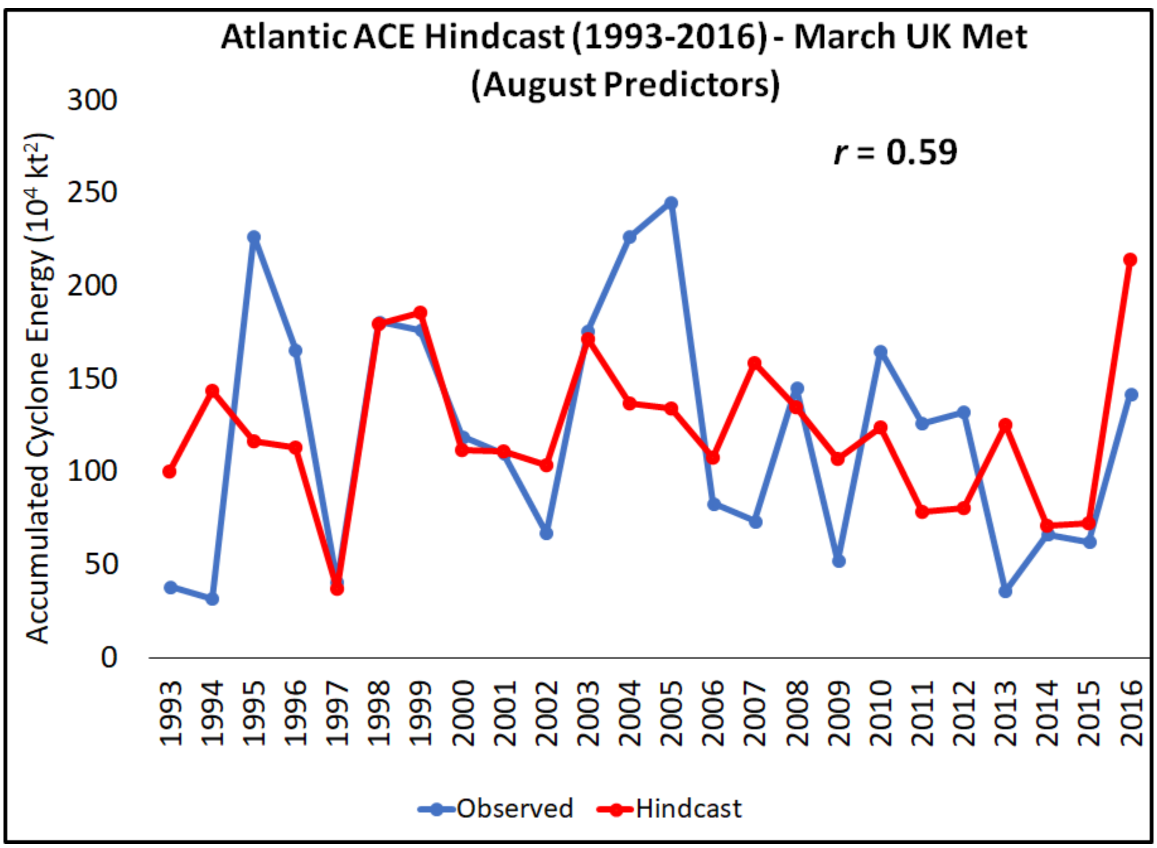


Figure 9: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the UK Met Office.

Table 7: Statistical/dynamical model output from the UK Met Office for the 2024 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	Met Office Hybrid Forecast	Final Forecast
Named Storms (14.4)	23.2	23
Named Storm Days (69.4)	119.1	115
Hurricanes (7.2)	12.4	11
Hurricane Days (27.0)	54.0	45
Major Hurricanes (3.2)	6.3	5
Major Hurricane Days (7.4)	17.2	13
Accumulated Cyclone Energy Index (123)	241	210
Net Tropical Cyclone Activity (135%)	255	220

c) JMA Met Office Statistical/Dynamical Model Forecast

Table 8 displays the JMA forecasts of the August parameters for 2024 from a 1 March initialization date. The ensemble average from the JMA dynamical model is calling for a warmer central/eastern North Atlantic than in any year in the hindcast period from 1993–2020 and a weak La Niña. Figure 10 displays hindcasts for the JMA of ACE from 1993–2020, while Table 9 presents the forecast from the JMA for the 2024 Atlantic hurricane season. The statistical/dynamical model based off of JMA is also calling for an extremely active Atlantic hurricane season in 2024.

Table 8: Listing of predictions of August large-scale conditions from JMA model output, initialized on 1 March. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2024 Forecast	Effect on 2024 Hurricane Season
1) JMA Prediction of August SST (10–45°N, 60–20°W) (+)	+3.3 SD	Strongly Enhance
2) JMA Prediction of August SST (5°S–5°N, 180–90°W) (-)	-0.8 SD	Enhance

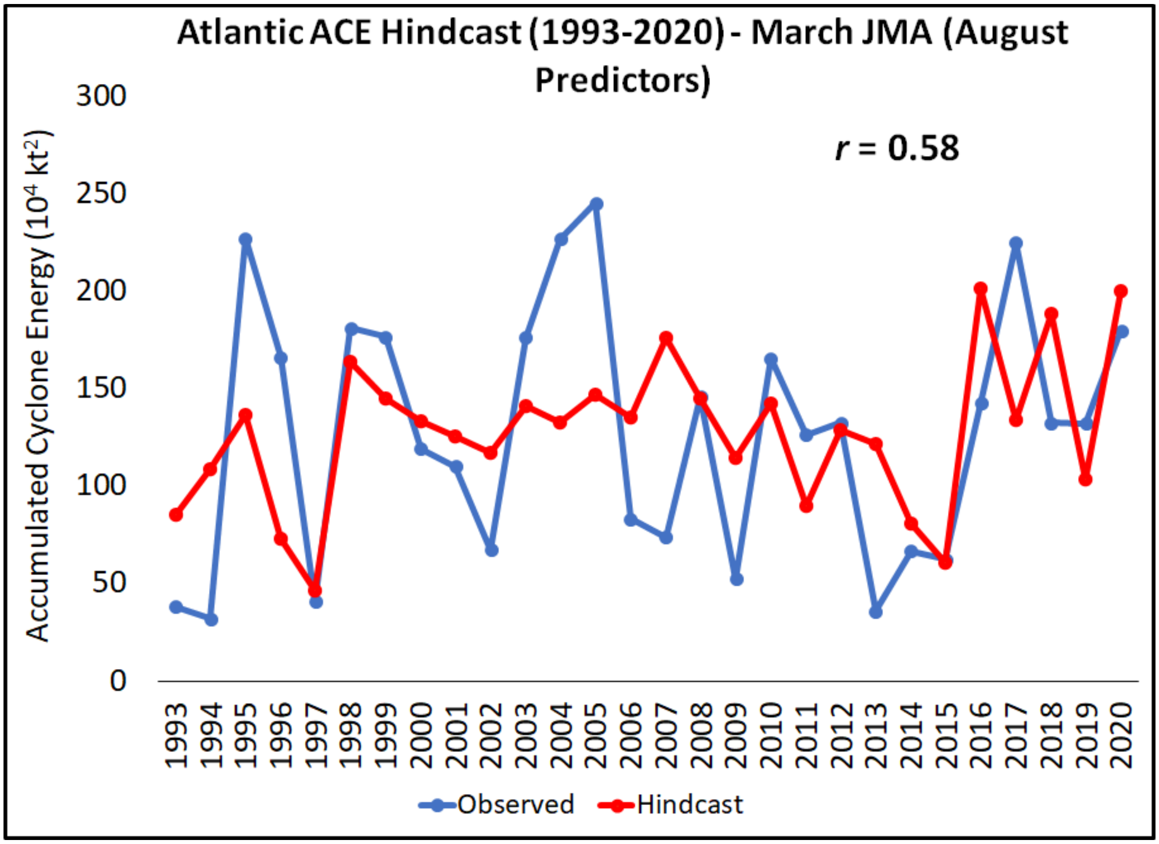


Figure 10: Observed versus statistical/dynamical hindcast values of ACE for 1993–2020 from the JMA.

Table 9: Statistical/dynamical model output from the JMA for the 2024 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	JMA Hybrid Forecast	Final Forecast
Named Storms (14.4)	22.4	23
Named Storm Days (69.4)	114.0	115
Hurricanes (7.2)	11.8	11
Hurricane Days (27.0)	51.3	45
Major Hurricanes (3.2)	6.0	5
Major Hurricane Days (7.4)	16.2	13
Accumulated Cyclone Energy Index (123)	229	210
Net Tropical Cyclone Activity (135%)	243	220

d) CMCC Statistical/Dynamical Model Forecast

Table 10 displays the CMCC forecasts of the August parameters for 2024 from a 1 March initialization date. The ensemble average from the CMCC dynamical model is calling for a warmer central/eastern North Atlantic than in any year in the hindcast period from 1993–2016 and a robust La Niña. Figure 11 displays hindcasts for the CMCC of

ACE from 1993–2016, while Table 11 presents the forecast from the CMCC for the 2024 Atlantic hurricane season. The statistical/dynamical model based off of CMCC is calling for the most ACE on record for an Atlantic hurricane season, primarily due to an even warmer eastern/central tropical Atlantic than the other model guidance is predicting.

Table 10: Listing of predictions of August large-scale conditions from CMCC model output, initialized on 1 March. A plus (+) means that positive deviations of the parameter are associated with increased hurricane activity, while a minus (-) means that negative deviations of the parameter are associated with increased hurricane activity.

Predictor	Values for 2024 Forecast	Effect on 2024 Hurricane Season
1) CMCC Prediction of August SST (10–45°N, 60–20°W) (+)	+4.8 SD	Strongly Enhance
2) CMCC Prediction of August SST (5°S–5°N, 180–90°W) (-)	-1.5 SD	Enhance

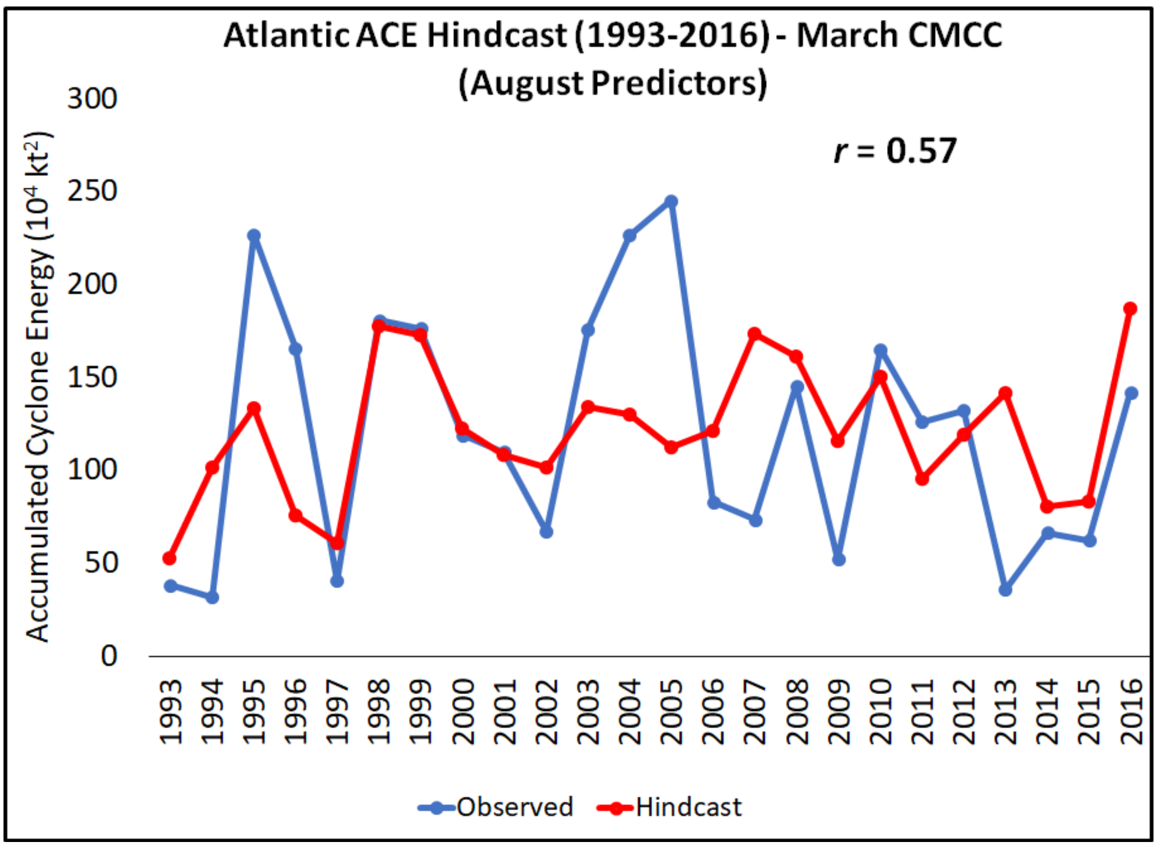


Figure 11: Observed versus statistical/dynamical hindcast values of ACE for 1993–2016 from the CMCC.

Table 11: Statistical/dynamical model output from the CMCC for the 2024 Atlantic hurricane season and the final adjusted forecast.

Forecast Parameter and 1991–2020 Average (in parentheses)	CMCC Hybrid Forecast	Final Forecast
Named Storms (14.4)	25.6	23
Named Storm Days (69.4)	135.4	115
Hurricanes (7.2)	14.1	11
Hurricane Days (27.0)	63.0	45
Major Hurricanes (3.2)	7.3	5
Major Hurricane Days (7.4)	20.4	13
Accumulated Cyclone Energy Index (123)	280	210
Net Tropical Cyclone Activity (135%)	294	220

2.3 April Analog Forecast Scheme

Certain years in the historical record have global oceanic and atmospheric trends which are similar to 2024. These years also provide useful clues as to likely levels of activity that the forthcoming 2024 hurricane season may bring. For this early April extended range forecast, we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current March 2024 conditions and, more importantly, projected August–October 2024 conditions. Table 12 lists our analog selections, while Figure 12 shows the composite August–October SST in our five analog years.

We searched for years that were generally characterized by El Niño conditions the previous winter and had La Niña conditions during the peak of the Atlantic hurricane season (August–October). We also selected years that had well above-average SSTs in the tropical Atlantic, although none of these years had SSTs in the tropical Atlantic in March that were as warm as they are now. We anticipate that the 2024 hurricane season will have activity near the average of our five analog years for most parameters. The busy hurricane seasons in all analog years underscore the higher-than-normal confidence in an active 2024 hurricane season. Named storm activity was likely significantly underestimated in 1878 and 1926 given the extremely limited observational network available in those years.

Table 12: Analog years for 2024 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1878	12	90.00	10	50.25	2	10.00	180.9	161.6
1926	11	86.75	8	58.50	6	22.75	229.6	230.3
1998	14	87.25	10	48.50	3	9.50	181.2	168.6
2010	19	89.50	12	38.50	5	11.00	165.5	196.4
2020	30	122.75	14	35.25	7	8.25	180.4	235.5
Average	17.2	95.3	10.8	46.2	4.6	12.3	187.5	198.5
2024 Forecast	**23**	**115**	**11**	**45**	**5**	**13**	**210**	**220**

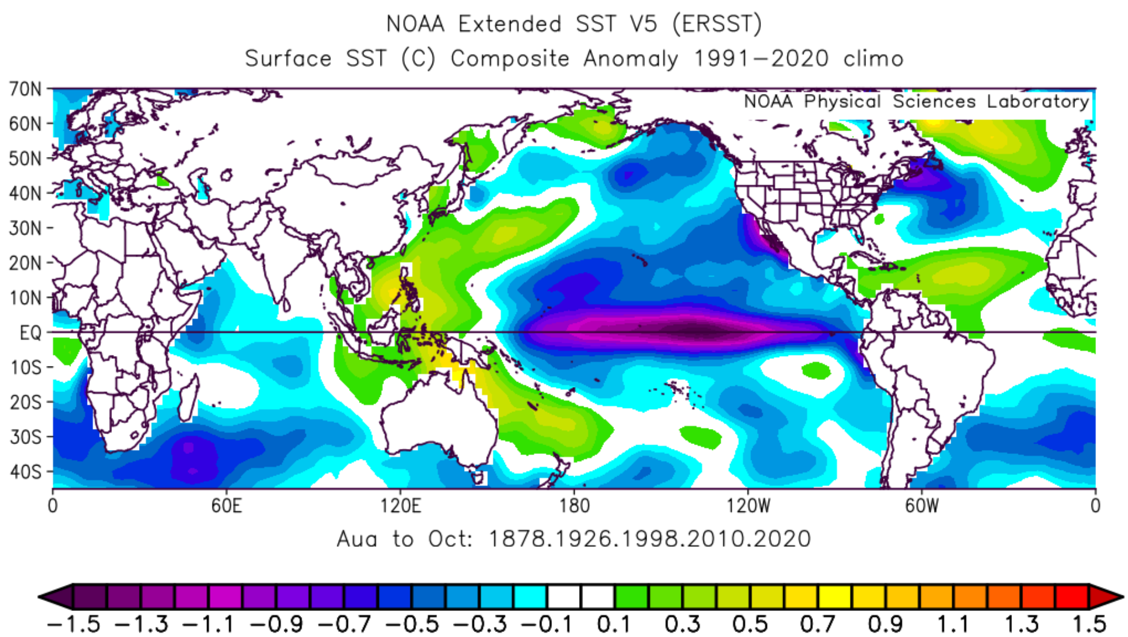


Figure 12: Average August–October SST anomalies in our five analog years.

2.4 ACE West of 60°W Forecast

We now explicitly forecast ACE occurring west of 60°W. While there is a relatively robust relationship between basinwide ACE and North Atlantic landfalling hurricanes (defined as hurricanes making landfall west of 60°W), there is an improved relationship between North Atlantic landfalling hurricanes and ACE west of 60°W (Figures 13 and 14) since 1950.

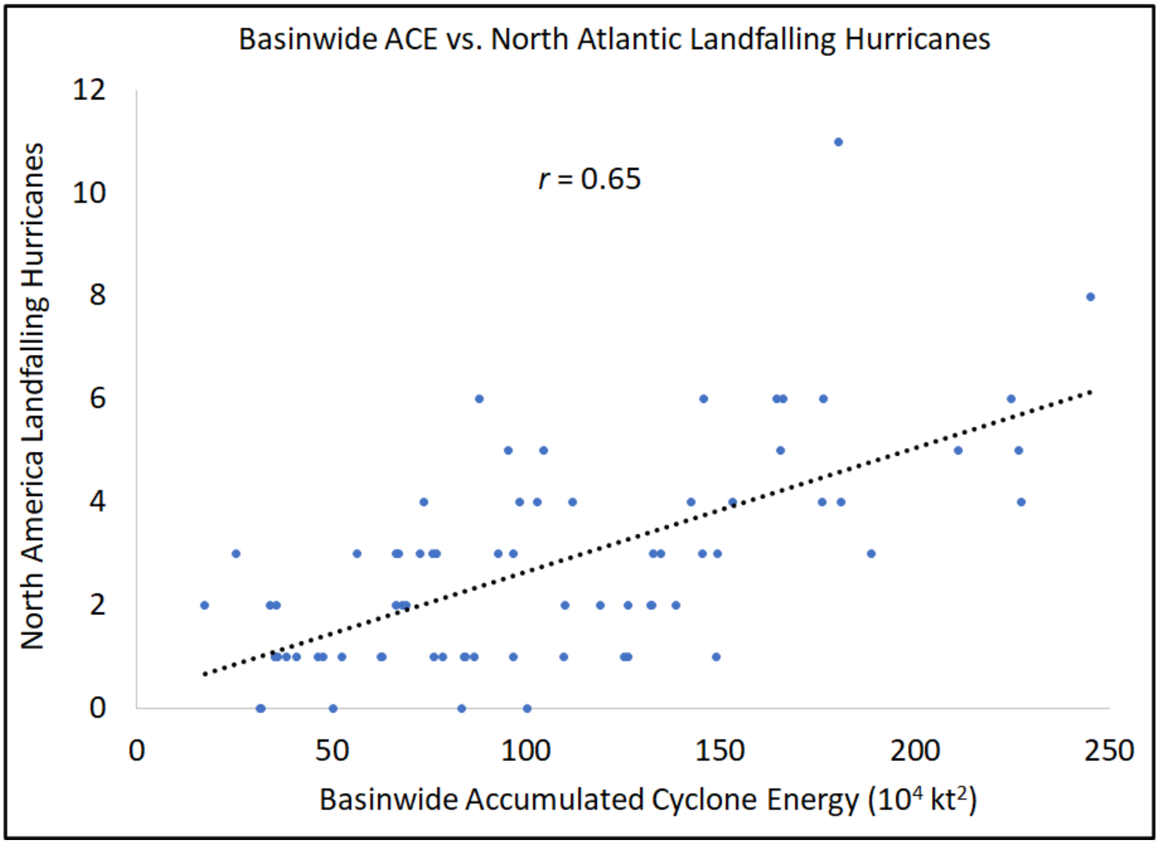


Figure 13: Scatterplot showing relationship between basinwide ACE and North Atlantic landfalling hurricanes.

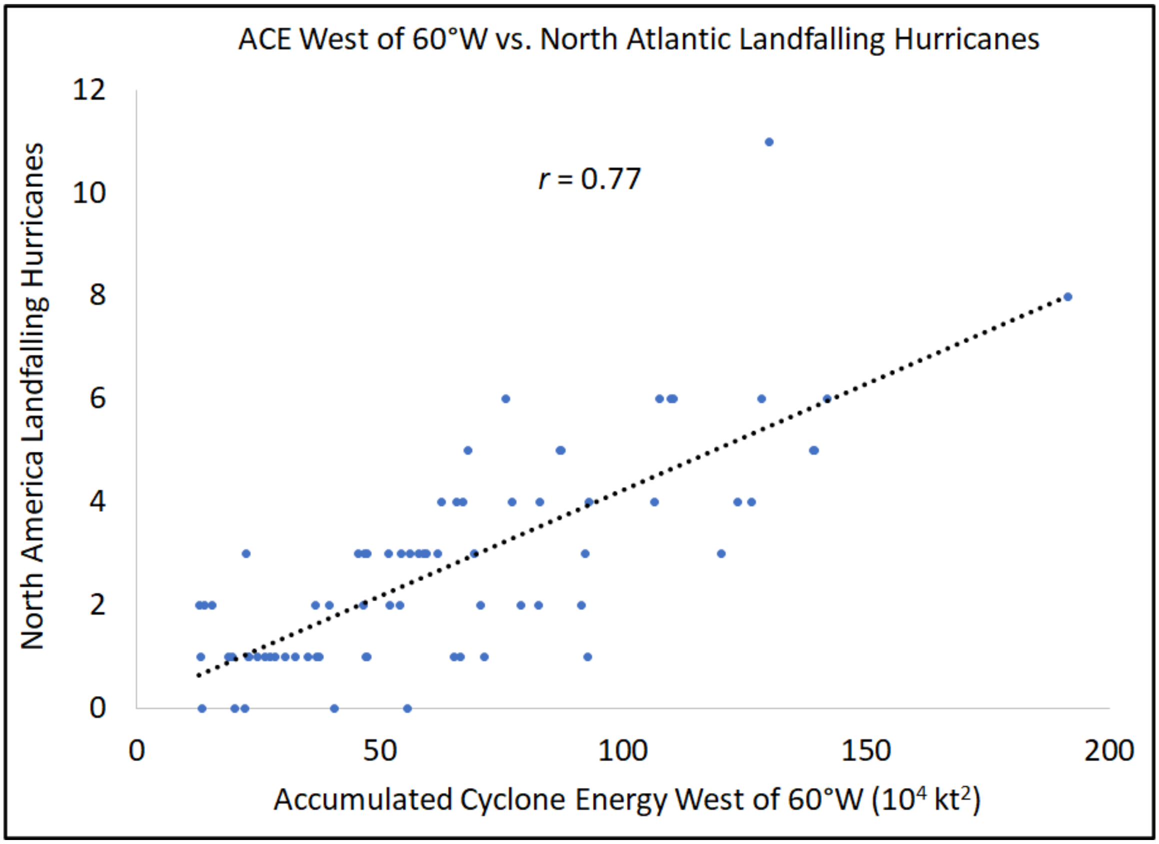


Figure 14: Scatterplot showing relationship between ACE west of 60°W and North Atlantic landfalling hurricanes.

In general, years characterized by El Niño conditions tend to have slightly less ACE west of 60°W than La Niña seasons, likely due to both more conducive conditions in the western Atlantic in La Niña seasons, as well as an increased chance of recurvature for TCs in El Niño seasons (Colbert and Soden 2012). This was certainly the case in 2023. A strong El Niño occurred, the subtropical high was quite weak, and many of the TCs that occurred recurved east of 60°W. We use data from 1979–2022 and base ENSO classifications on the August–October-averaged Oceanic Nino Index (ONI). Years with an ONI >= 0.5°C are classified as El Niño, years with an ONI <= -0.5°C are classified as La Niña, while all other seasons are classified as neutral ENSO.

We find that 52% of basinwide ACE occurs west of 60°W in El Niño years, while 60% of basinwide ACE occurs west of 60°W in La Niña years. In neutral ENSO years, 59% of basinwide ACE occurs west of 60°W. Given that we are favoring La Niña with this outlook, we are estimating ~60% of basinwide ACE to occur west of 60°W in 2024.

2.5 April Forecast Summary and Final Adjusted Forecast

Table 13 shows our final adjusted early April forecast for the 2024 season which is a combination of our statistical scheme, statistical/dynamical schemes, and analog scheme as well as qualitative adjustments for other factors not explicitly contained in any of these schemes. All of our forecast model guidance is calling for a hyperactive season. While there remains considerable uncertainty with any seasonal hurricane forecast issued in early April, the confidence in our prediction is higher than normal for an early April outlook. This is our highest prediction that we have ever issued with our April outlook. Our prior highest April forecast was for nine hurricanes, which we have called for several times since we began issuing April forecasts in 1995.

Table 13: Summary of our early April statistical forecast, our statistical/dynamical forecasts, our analog forecast, the average of these six schemes and our adjusted final forecast for the 2024 hurricane season.

Forecast Parameter and 1991–2020 Average (in parentheses)	Statistical Scheme	ECMWF Scheme	Met Office Scheme	JMA Scheme	CMCC Scheme	Analog Scheme	6-Scheme Average	Adjusted Final Forecast
Named Storms (14.4)	24.9	22.7	23.2	22.4	25.6	17.2	22.7	23
Named Storm Days (69.4)	130.8	115.7	119.1	114.0	135.4	95.3	118.4	115
Hurricanes (7.2)	13.6	12.0	12.4	11.8	14.1	10.8	12.5	11
Hurricane Days (27.0)	60.4	52.2	54.0	51.3	63.0	46.2	54.5	45
Major Hurricanes (3.2)	7.0	6.1	6.3	6.0	7.3	4.6	6.2	5
Major Hurricane Days (7.4)	19.5	16.5	17.2	16.2	20.4	12.3	17.0	13
Accumulated Cyclone Energy Index (123)	269	233	241	229	280	188	240	210
Net Tropical Cyclone Activity (135%)	283	247	255	243	294	199	254	220

3 Forecast Uncertainty

This season we continue to use probability of exceedance curves as discussed in Saunders et al. (2020) to quantify forecast uncertainty. In that paper, we outlined an approach that uses statistical modeling and historical skill of various forecast models to arrive at a probability that particular values for hurricane numbers and ACE would be exceeded. Here we display probability of exceedance curves for hurricanes and ACE (Figures 15 and 16), using the error distributions calculated from both normalized cross-validated statistical as well as the cross-validated statistical/dynamical hindcasts from SEAS5. Hurricane numbers are fit to a Poisson distribution, while ACE is fit to a Weibull distribution. Table 14 displays one standard deviation uncertainty ranges (~68% of all forecasts within this range). This uncertainty estimate is also very similar to the 70% uncertainty range that NOAA provides with its forecasts. We use Poisson distributions for all storm parameters (e.g., named storms, hurricanes and major hurricanes) while we use a Weibull distribution for all integrated parameters except for major hurricane days (e.g., named storm days, ACE, etc.). We use a Laplace distribution for major hurricane days. As noted earlier, we are more confident than normal for an April forecast given how robust our primary predictors are (e.g., likely La Niña, extremely warm Atlantic sea surface temperatures) for an active Atlantic hurricane season.

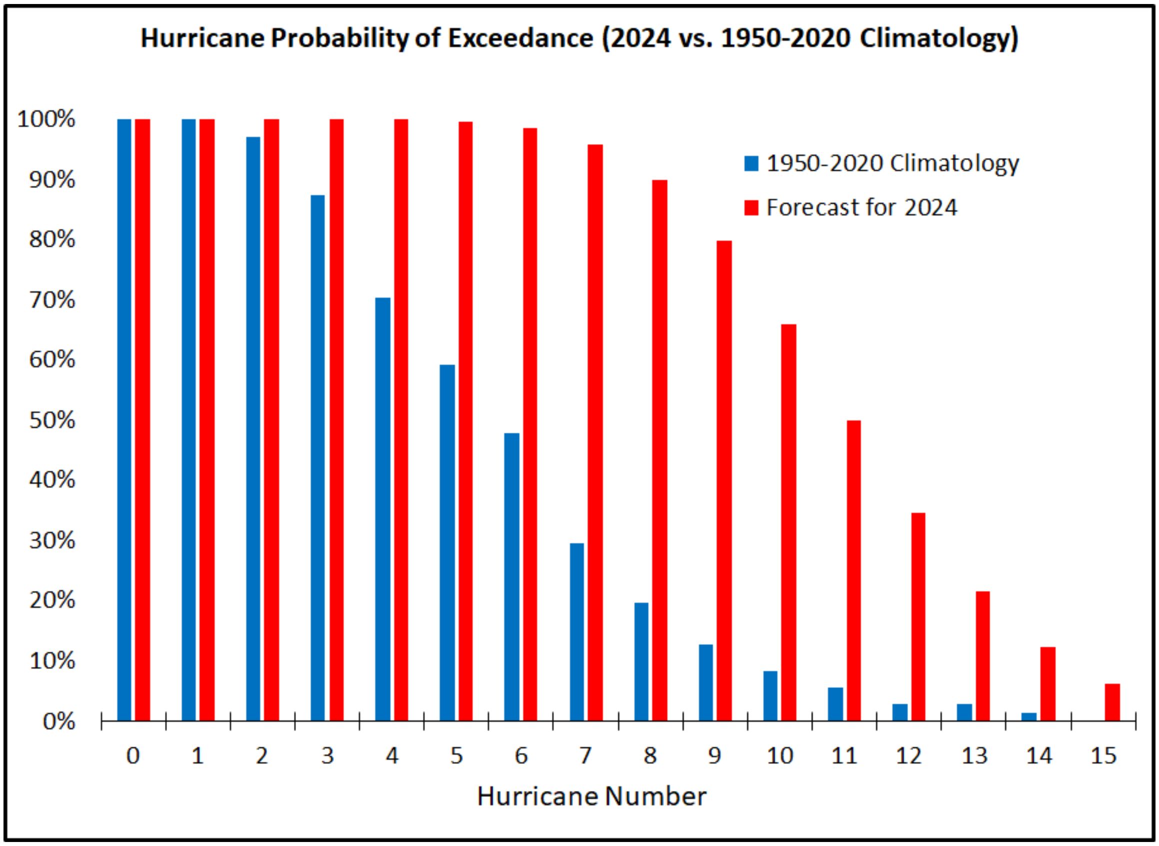


Figure 15: Probability of exceedance plot for hurricane numbers for the 2024 Atlantic hurricane season. The values on the x-axis indicate that the number of hurricanes exceeds that specific number. For example, 97% of Atlantic hurricane seasons from 1950–2020 have had more than two hurricanes.

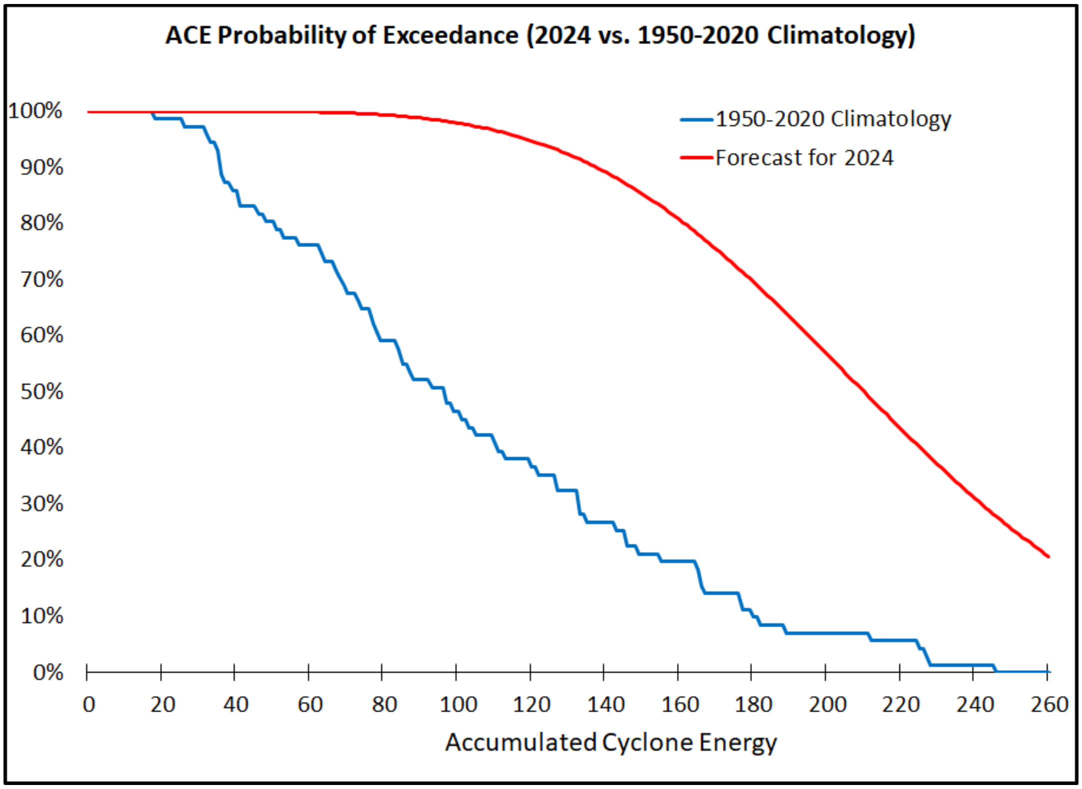


Figure 16: As in Figure 15 but for ACE.

Table 14: Forecast ranges for each parameter. Note that the forecast spread may not be symmetric around the mean value, given the historical distribution of tropical cyclone activity.

Parameter	2024 Forecast	Uncertainty Range (68% of Forecasts Likely to Fall in This Range)
Named Storms (NS)	23	19 – 27
Named Storm Days (NSD)	115	91 – 130
Hurricanes (H)	11	8 – 14
Hurricane Days (HD)	45	30 – 61
Major Hurricanes (MH)	5	3 – 7
Major Hurricane Days (MHD)	13	8 – 20
Accumulated Cyclone Energy (ACE)	210	151 – 260
ACE West of 60°W	125	83 – 172
Net Tropical Cyclone (NTC) Activity	220	164 – 279

4 ENSO

Over the past several months, El Niño conditions in the tropical Pacific have gradually weakened (Figure 17). SST anomalies have decreased across the entire tropical Pacific, with the strongest anomalous cooling taking place in the far eastern tropical Pacific. Figure 18 displays the locations of the various Nino regions displayed in Figure 17.

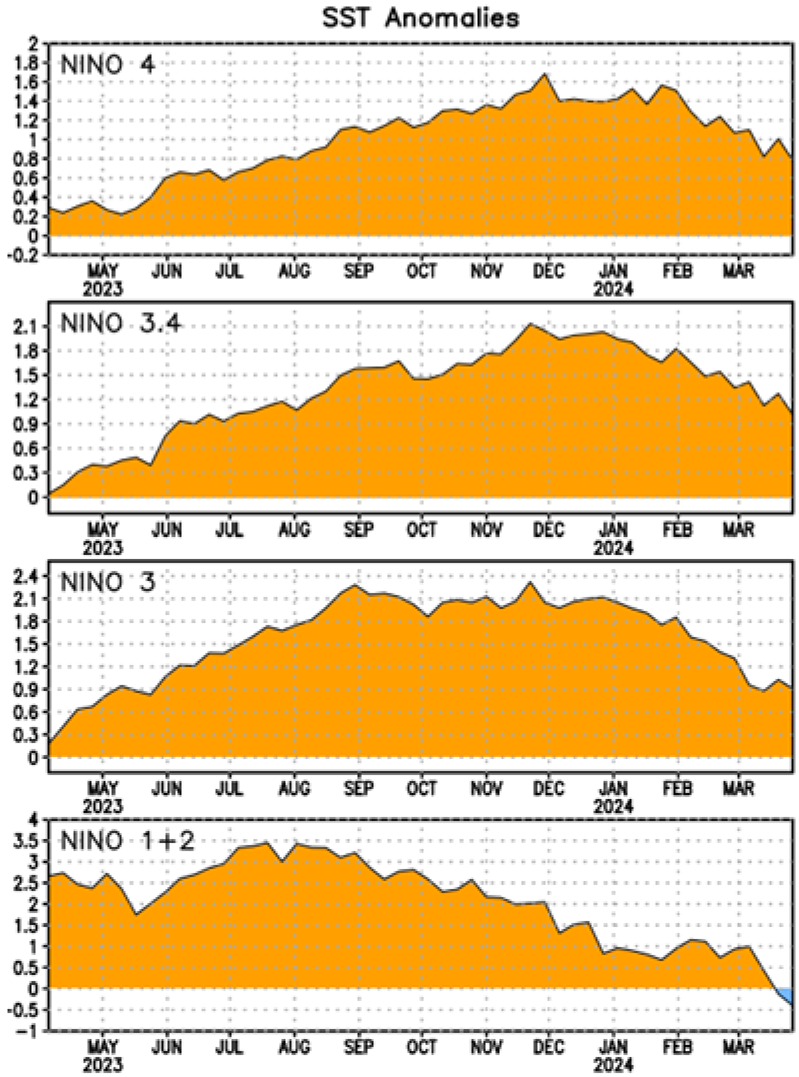


Figure 17: SST anomalies for several ENSO regions over the past year. Figure courtesy of Climate Prediction Center.

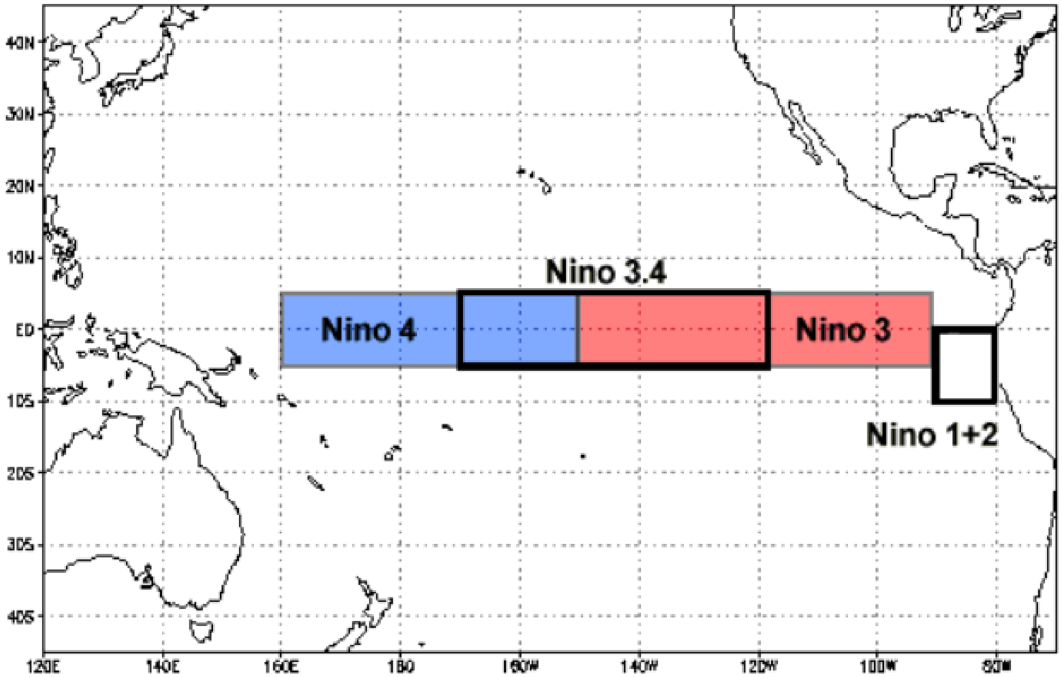


Figure 18: Location of ENSO SST regions used in Figure 17. Figure courtesy of the National Centers for Environmental Information.

Upper-ocean heat content anomalies in the eastern and central tropical Pacific have decreased rapidly over the past several weeks and have recently become negative (Figure 19). Anomalously strong trade winds have triggered two upwelling oceanic Kelvin waves. These upwelling oceanic Kelvin waves have caused anomalous cooling in the eastern and central tropical Pacific.

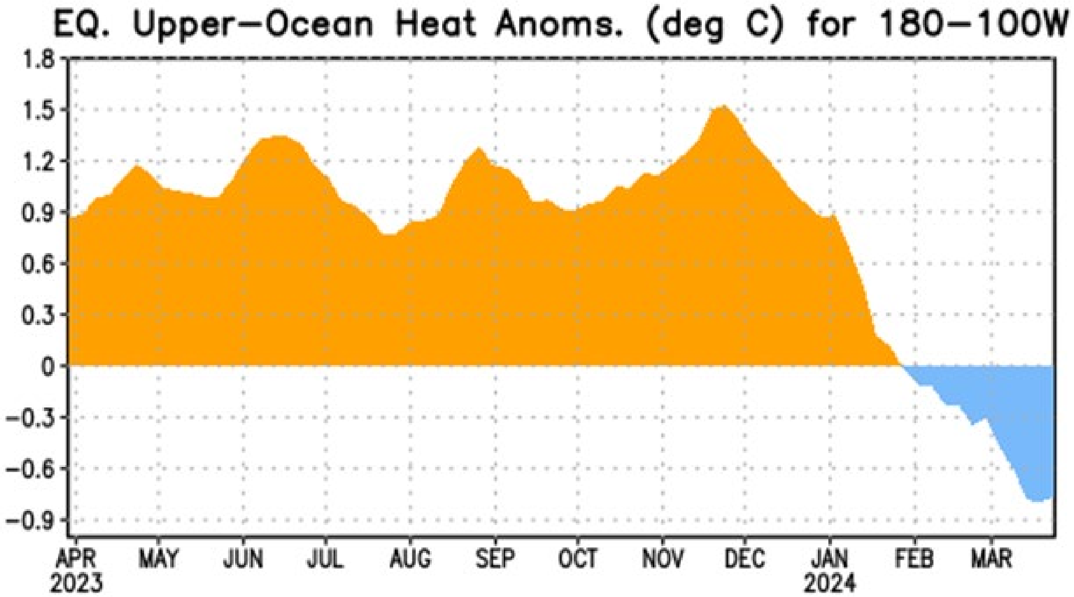


Figure 19: Central and eastern equatorial Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Figure courtesy of Climate Prediction Center.

SSTs remain above-normal across most of the equatorial Pacific, with slightly below-normal SSTs beginning to emerge in parts of the far eastern tropical Pacific (Figure 20). The western North Pacific is warmer than normal, while the current spatial pattern of SSTs in the North Pacific (e.g., well above-average SST anomalies across most of the North Pacific and near to slightly above-average SSTs off the west coast of California) are indicative of a negative phase of the Pacific Decadal Oscillation.

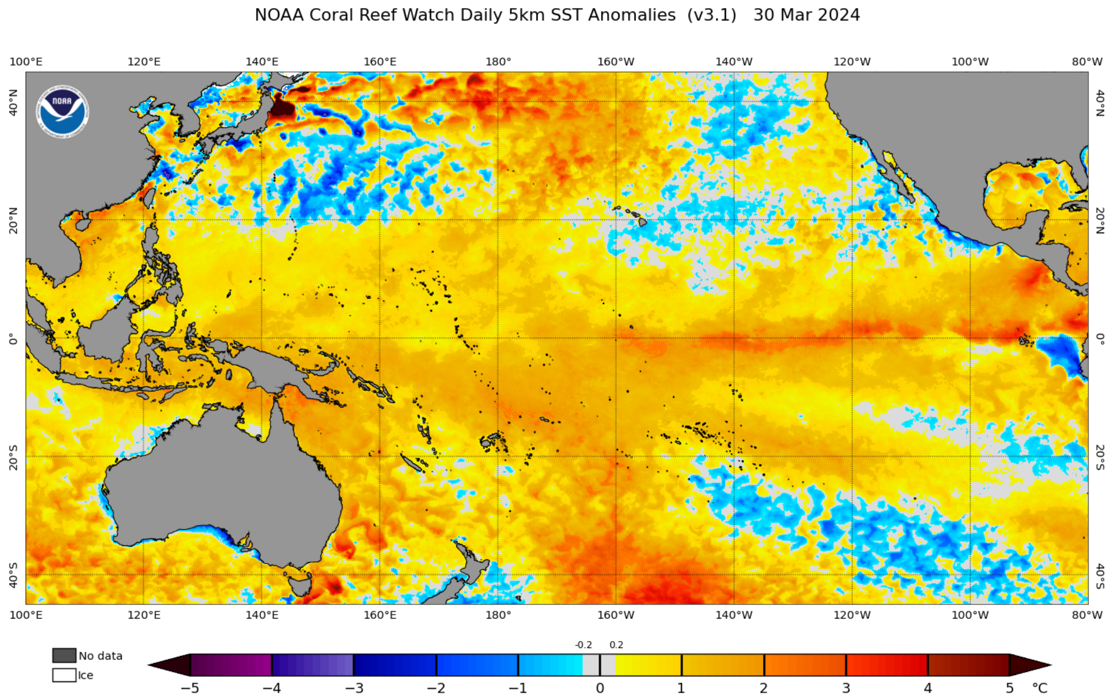


Figure 20: Current SST anomalies across the tropical and subtropical Pacific.

Table 15 displays January and March SST anomalies for several Nino regions. Over the past two months, SST anomalies across the entire eastern and central tropical Pacific have cooled.

Table 15: January and March SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. March-January SST anomaly differences are also provided.

Region	January SST Anomaly (°C)	March SST Anomaly (°C)	March – January SST Anomaly (°C)
Nino 1+2	+0.8	+0.3	-0.5
Nino 3	+1.9	+0.9	-1.0
Nino 3.4	+1.8	+1.2	-0.6
Nino 4	+1.5	+0.9	-0.6

An upwelling (cooling) oceanic Kelvin wave, denoted by the short dashed line, is currently approaching the west coast of South America after transiting most of the tropical Pacific (Figure 21). Another upwelling oceanic Kelvin wave has recently formed and is propagating eastward across the central tropical Pacific. As mentioned earlier, these Kelvin waves are typically triggered by anomalous low-level winds in the tropical Pacific. These upwelling Kelvin waves were likely forced by anomalous low-level easterlies that occurred to the west of the International Date Line (180°W) in early to mid-January and mid-February, respectively (Figure 22).

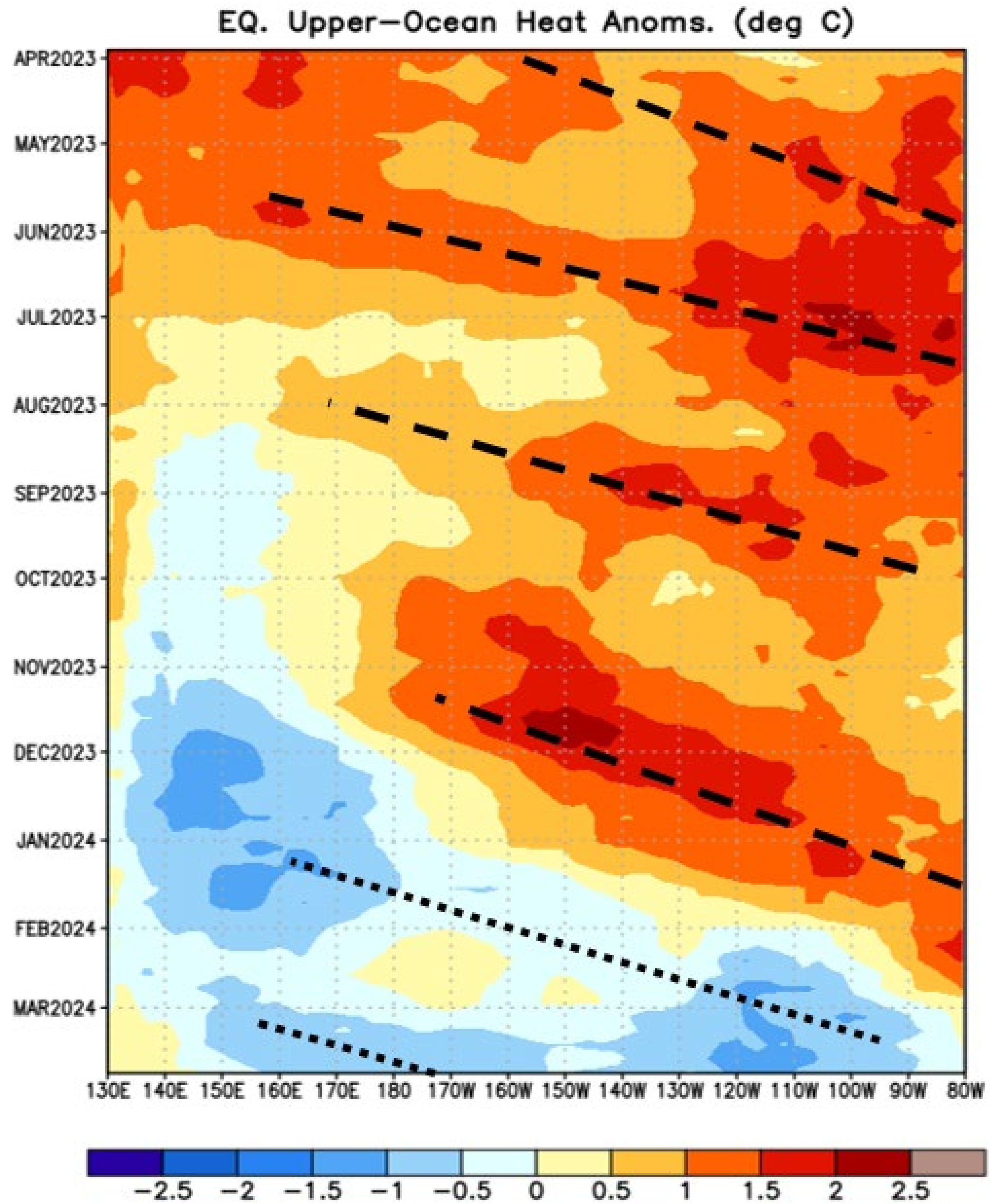


Figure 21: Upper-ocean (0–300 meter) heat content anomalies in the tropical Pacific since April 2023. Long dashed lines indicate downwelling Kelvin waves, while short dashed lines indicate upwelling Kelvin waves. Downwelling Kelvin waves result in upper-ocean heat content increases, while upwelling Kelvin waves result in upper-ocean heat content decreases. Figure courtesy of Climate Prediction Center.

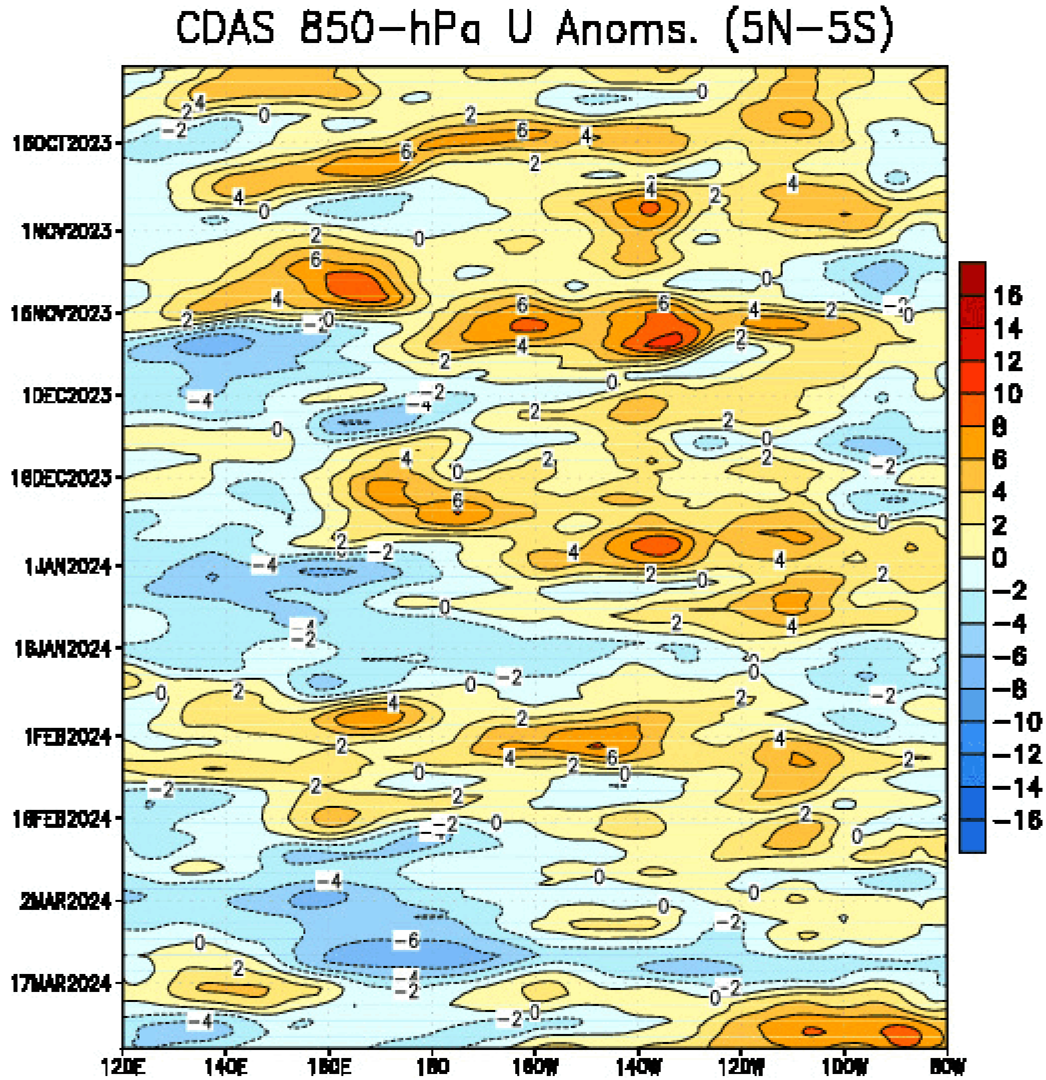


Figure 22: Anomalous equatorial low-level winds spanning from 120°E to 80°W. Figure courtesy of Climate Prediction Center.

Over the next several months, we will be closely monitoring low-level winds over the tropical Pacific. Anomalous low-level easterlies are forecast to develop to the west of the International Date Line and likely persist and expand eastward for the next couple of weeks (Figure 23). This is another signal that El Niño conditions are weakening and are likely to transition to neutral ENSO conditions in the next couple of months.

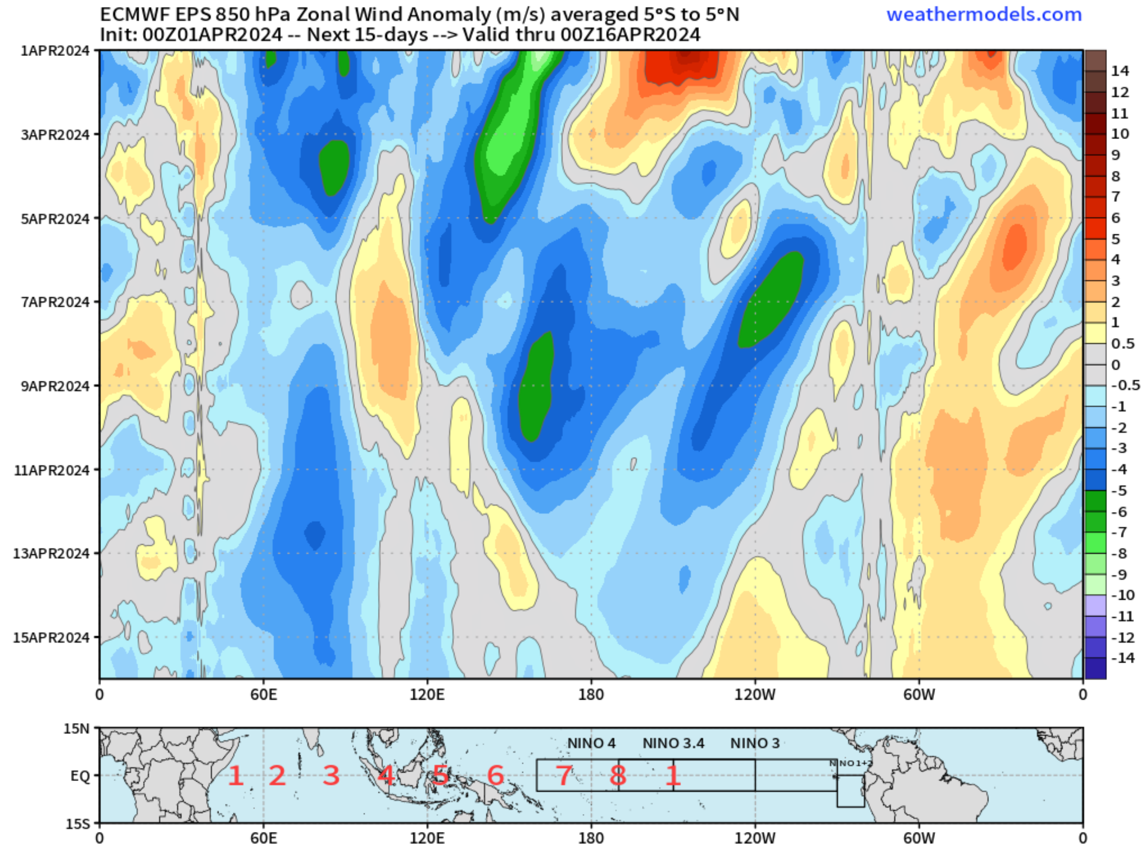


Figure 23: Forecast 850-hPa zonal equatorial winds for the next 15 days. Figure courtesy of weathermodels.com.

There is always considerable uncertainty with the future state of El Niño during the Northern Hemisphere spring. The latest plume of ENSO predictions from several statistical and dynamical models shows considerable spread by the peak of the Atlantic hurricane season in August–October (Figure 24). However, all models are forecasting El Niño to be gone, with most models forecasting La Niña to develop by the peak of the Atlantic hurricane season.

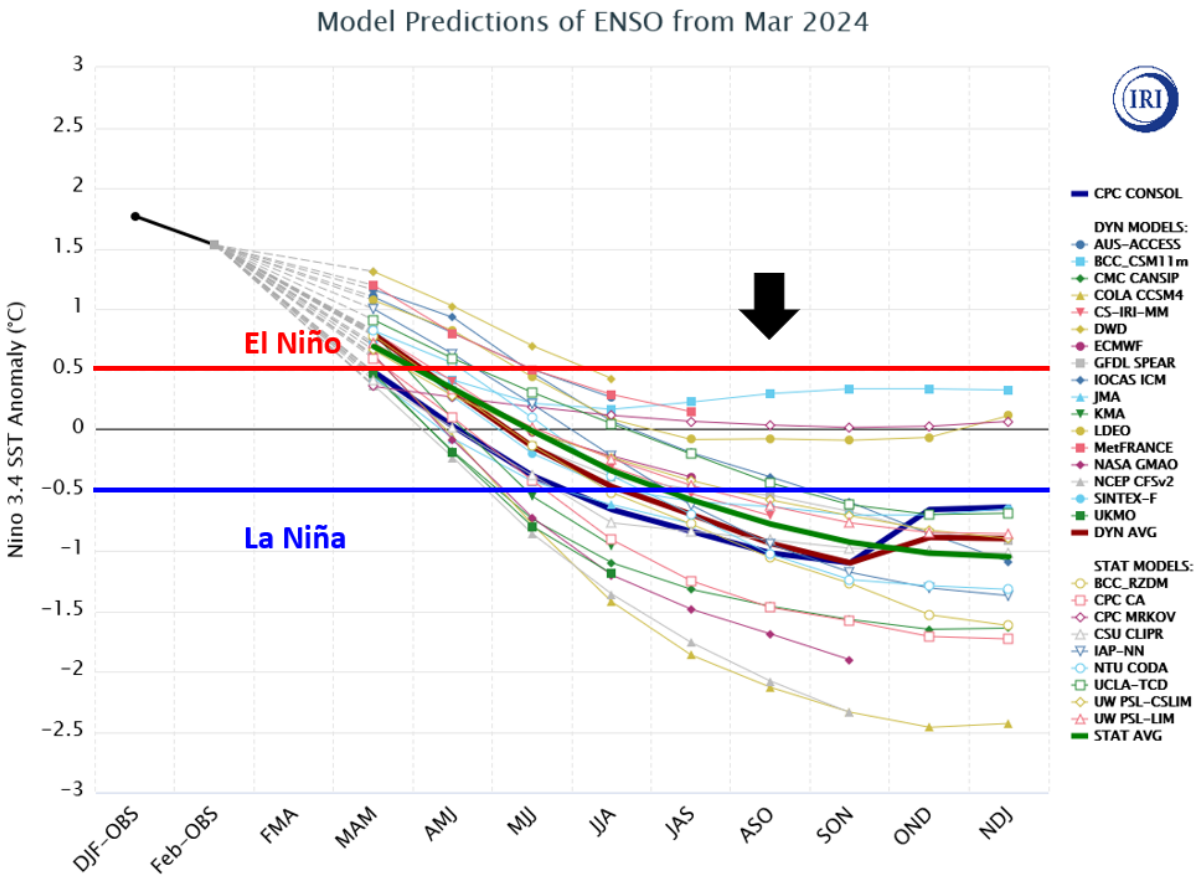


Figure 24: ENSO forecasts from various statistical and dynamical models for Nino 3.4 SST anomalies based on late February to early March initial conditions. All models call for either ENSO neutral or La Niña or conditions for August–October. The black arrow delineates the peak of the Atlantic hurricane season (August–October). Figure courtesy of the International Research Institute (IRI).

The latest official forecast from NOAA strongly favors La Niña for August–October. NOAA is currently predicting an 82% chance of La Niña, a 17% chance of ENSO neutral conditions and a 1% chance of El Niño for the peak of the Atlantic hurricane season (Figure 25).

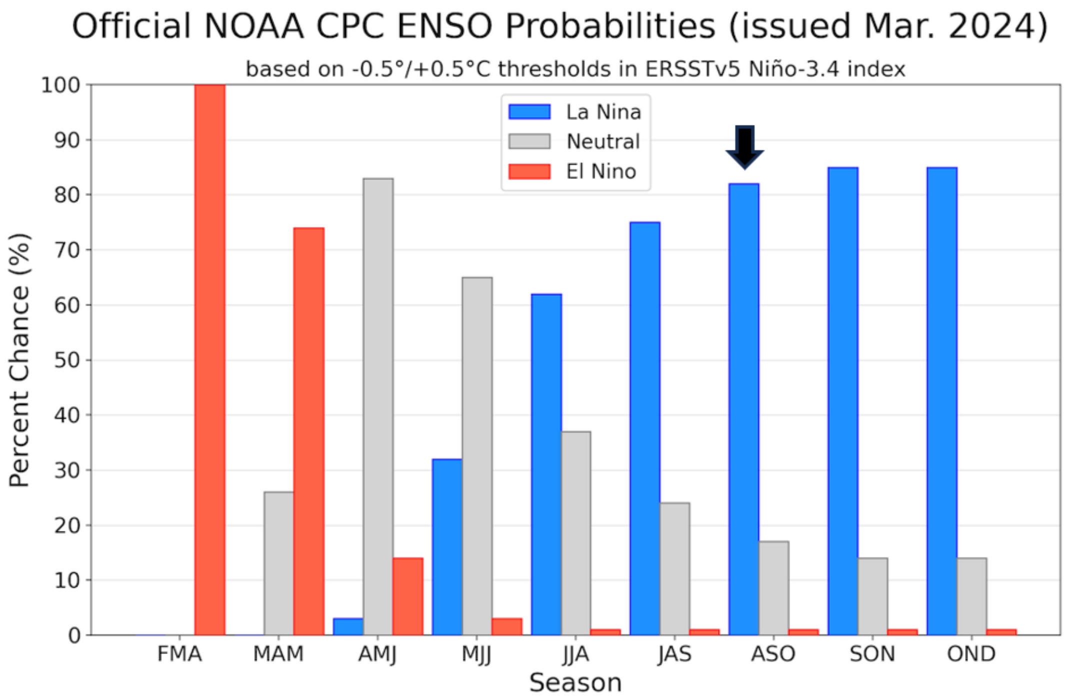


Figure 25: Official probabilistic ENSO forecast from NOAA. The black arrow delineates the peak of the Atlantic hurricane season (August–October).

Based on the above information, our best estimate is that we will have La Niña conditions for the peak of the Atlantic hurricane season. As noted earlier, there remains some uncertainty if we transition to La Niña. Even if we do not transition to La Niña, we would anticipate cool neutral ENSO conditions. Cool neutral ENSO conditions would still likely lead to a very busy Atlantic hurricane season given how hurricane-conducive current atmospheric-oceanic conditions are across the tropical and subtropical Atlantic (discussed in the next section).

5 Current Atlantic Basin Conditions

Currently, SSTs are at record warm levels across most of the tropical and the eastern part of the subtropical Atlantic (Figure 26). Over the past several months, trade winds across most of the tropical and the eastern subtropical Atlantic have been weaker than normal, helping to reinforce the extremely warm SSTs that have predominated across the Atlantic over the past ~12 months (Figure 27). Weaker trade winds lead to less evaporation and mixing, favoring anomalous warming. Figure 28 shows the forecast for the next ~2 weeks of low-level winds across the Atlantic. In general, trade winds are forecast to be near to slightly weaker than average, indicating that extremely warm SST anomalies are likely to continue. Overall, the current SST anomaly pattern correlates very well with what is typically seen in active Atlantic hurricane seasons (Figure 29).

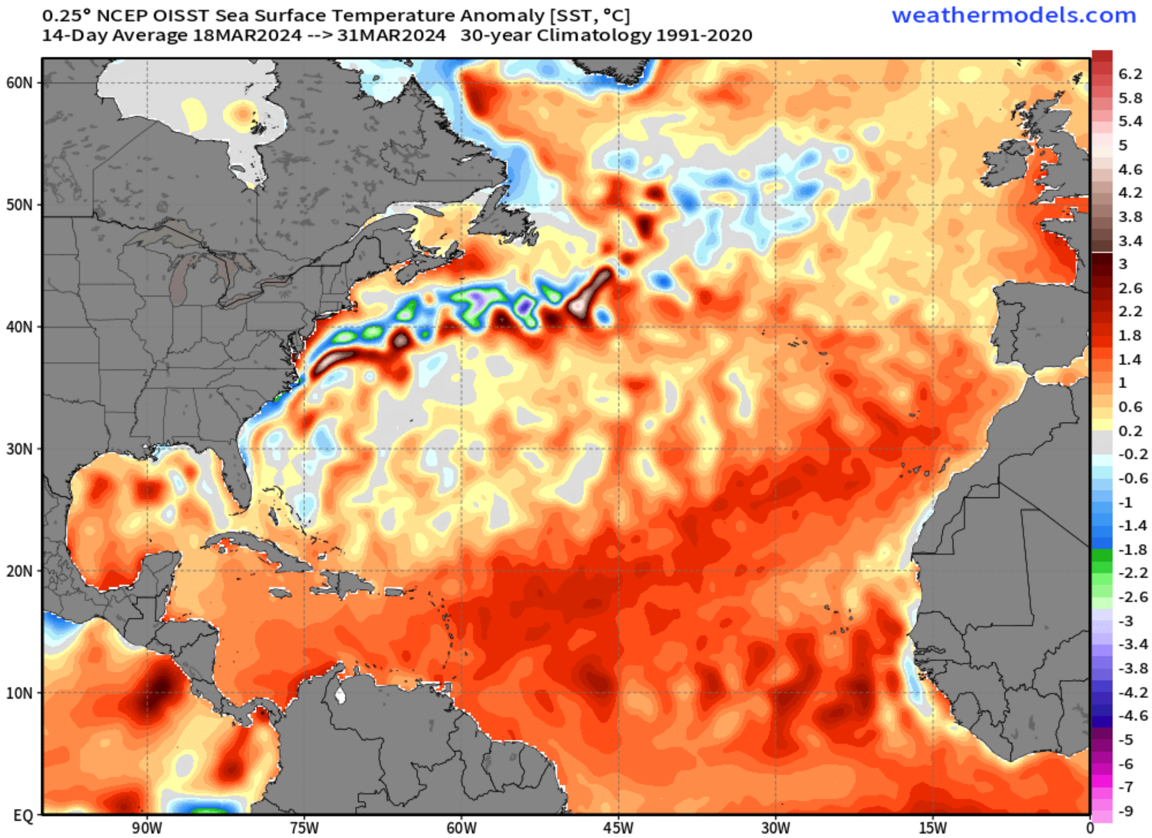


Figure 26: Late March 2024 North Atlantic SST anomalies.

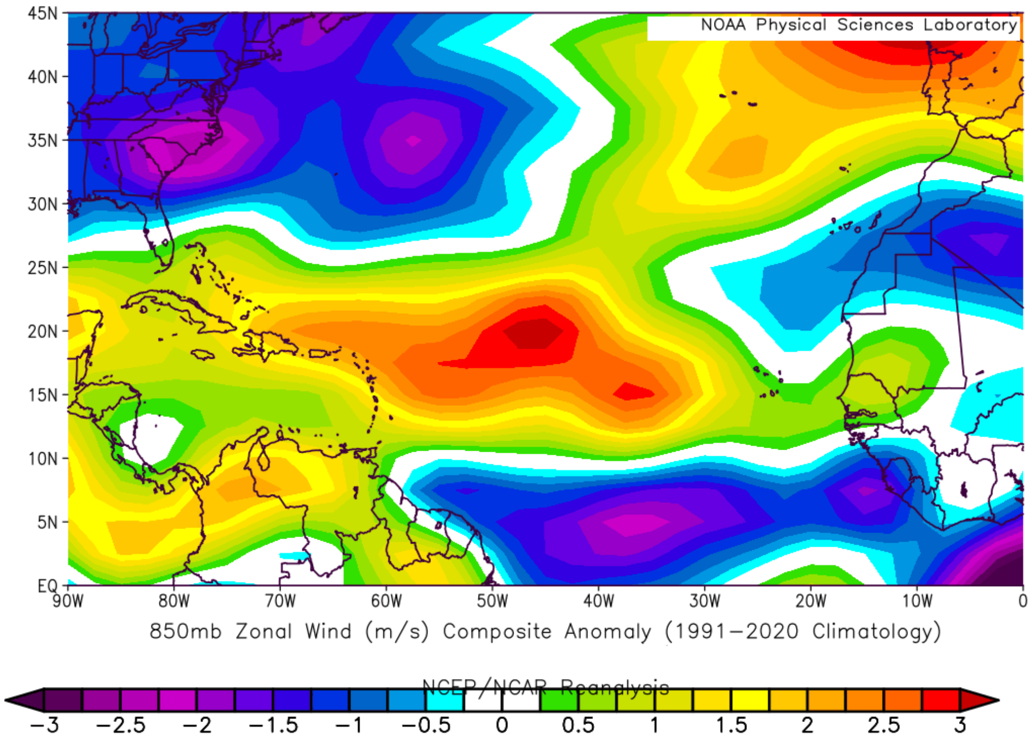


Figure 27: Zonal wind anomalies across the North Atlantic Ocean from December 2023 through March 2024.

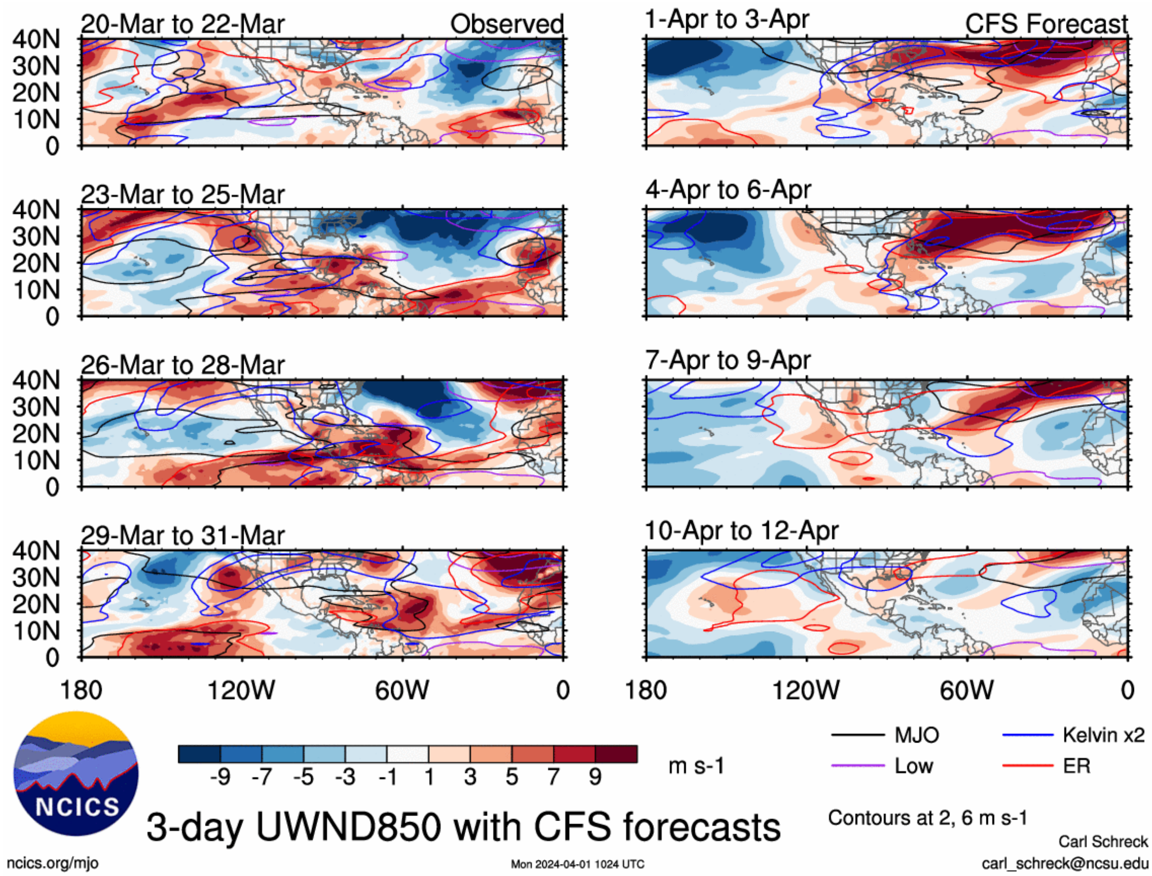


Figure 28: Observed low-level zonal winds across portions of the Western Hemisphere over the past four weeks and predicted low-level zonal winds from the Climate Forecast System through 12 April. Figure courtesy of Carl Schreck.

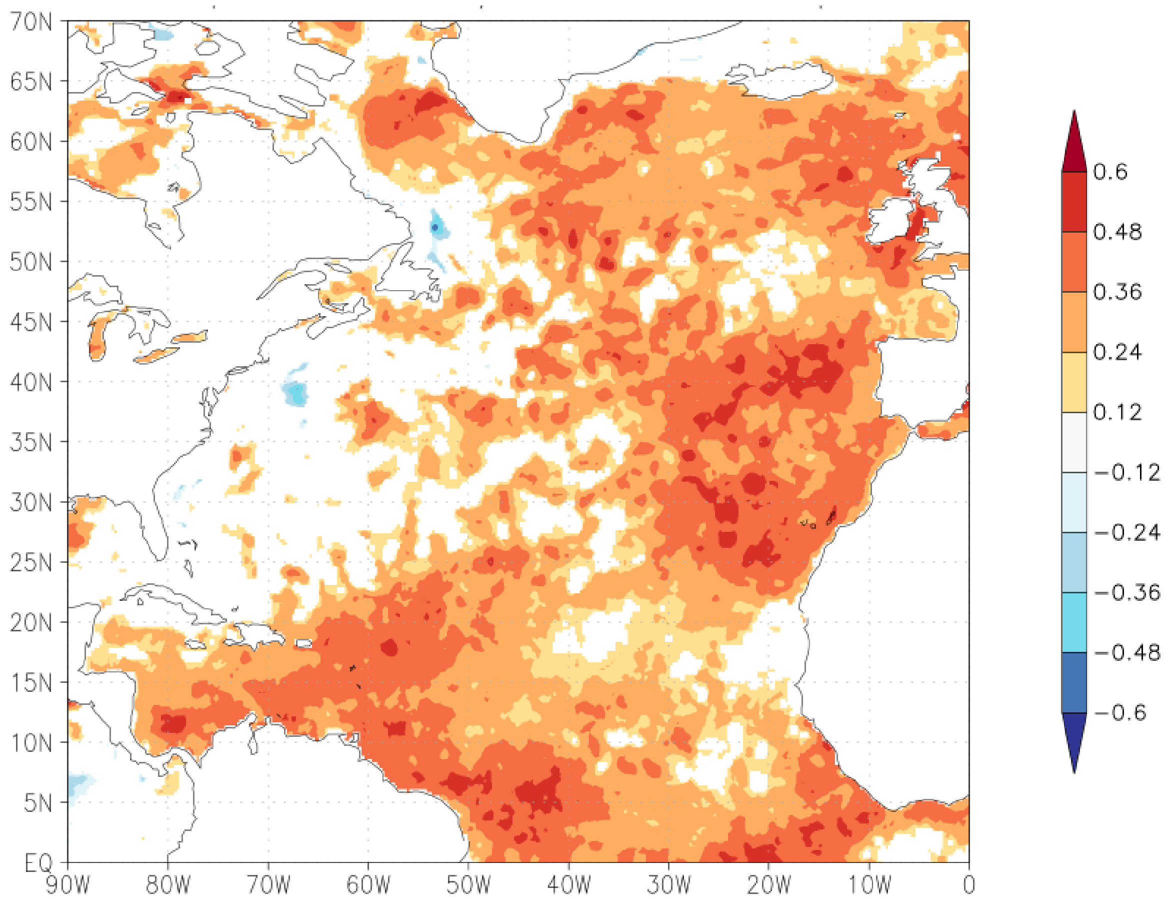


Figure 29: Rank correlations between April sea surface temperatures in the North Atlantic and annual Atlantic ACE from 1982–2023.

6 Tropical Cyclone Impact Probabilities for 2024

This year, we continue to calculate the impacts of tropical cyclones for each state and county/parish along the Gulf and East Coasts, tropical cyclone-prone provinces of Canada, states in Mexico, islands in the Caribbean and countries in Central America. We have used NOAA's Historical Hurricane Tracks website and selected all named storms, hurricanes and major hurricanes that have tracked within 50 miles of each landmass from 1880–2020. This approach allows for tropical cyclones that may have made landfall in an immediately adjacent region to be counted for all regions that were in close proximity to the landfall location of the storm. We then fit the observed frequency of storms within 50 miles of each landmass using a Poisson distribution to calculate the climatological odds of one or more events within 50 miles.

Net landfall probability is shown to be linked to overall Atlantic basin ACE. Long-term statistics show that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of hurricane landfalls for various landmasses in the basin. Beginning this year, we are adjusting landfall probabilities based on the ratio of predicted ACE west of 60°W to the average ACE west of 60°W, as almost all landmasses that we are issuing probabilities for are west of 60°W.

Table 16 displays the climatological odds of storms tracking within 50 miles of each state along the Gulf and East Coasts along with the odds in 2024. Landfall probabilities are well above their long-term averages. Probabilities for other Atlantic basin landmasses are available on our website.

Given that landfall rates between 1880–2020 and 1991–2020 are similar for the continental US, we adjust all landfall rates relative to the 1991–2020 Atlantic west of 60°W ACE climatology. We prefer to use 1880–2020 for landfall statistics to increase the robustness of the historical landfall dataset. Also, storms near landfall are likely better observed than those farther east in the basin prior to the satellite era (e.g., mid-1960s). Slight differences in ACE west of 60°W between the two periods (73 for 1991–2020 vs. 66 for 1880–2020) are likely mostly due to improved observational technology in the more recent period.

Table 16: Probability of >=1 named storm, hurricane and major hurricane tracking within 50 miles of each coastal state from Texas to Maine. Probabilities are provided for both the 1880–2020 climatological average as well as the probability for 2024, based on the latest CSU seasonal hurricane forecast.

State	2024 Probability >=1 Named Storm	2024 Probability event within 50 miles Hurricane	2024 Probability event within 50 miles Major Hurricane	Climatological Probability >=1 Named Storm	Climatological event within 50 miles Hurricane	Climatological event within 50 miles Major Hurricane
Alabama	78%	43%	14%	58%	28%	8%
Connecticut	35%	13%	2%	22%	8%	1%
Delaware	35%	10%	1%	23%	6%	1%
Florida	96%	75%	44%	86%	56%	29%
Georgia	82%	46%	10%	63%	30%	6%
Louisiana	84%	56%	23%	66%	38%	14%
Maine	34%	11%	2%	21%	7%	1%
Maryland	47%	18%	1%	31%	11%	1%
Massachusetts	49%	23%	5%	33%	14%	3%
Mississippi	72%	43%	13%	53%	28%	8%
New Hampshire	29%	9%	2%	18%	6%	1%
New Jersey	35%	11%	1%	23%	7%	1%
New York	41%	16%	4%	26%	9%	2%
North Carolina	85%	56%	13%	68%	38%	8%
Rhode Island	32%	13%	2%	20%	8%	1%
South Carolina	76%	44%	14%	57%	29%	8%
Texas	80%	54%	25%	61%	36%	16%
Virginia	65%	31%	2%	46%	20%	1%

7 Summary

An analysis of a variety of different atmosphere and ocean measurements (through March) which are known to have long-period statistical relationships with the upcoming season's Atlantic tropical cyclone activity, as well as output from dynamical models, indicate that 2024 will have well above-average activity. The big question marks with this season's predictions are if the extreme anomalous warmth in the tropical and eastern subtropical Atlantic persists or begins to weaken, as well as the strength of La Niña if it does develop.

8 Forthcoming Updated Forecasts of 2024 Hurricane Activity

We will be issuing seasonal updates of our 2024 Atlantic basin hurricane forecasts on **Tuesday 11 June**, **Tuesday 9 July, and Tuesday 6 August**. We will also be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August–October. A verification and discussion of all 2024 forecasts will be issued on **Tuesday, 26 November**. All of these forecasts will be available on our website.

9 Verification of Previous Forecasts

CSU's seasonal hurricane forecasts have shown considerable improvement in recent years, likely due to a combination of improved physical understanding, adoption of statistical/dynamical models and more reliable reanalysis products. Figure 30 displays correlations between observed and predicted Atlantic hurricanes from 1984–2013, from 2014–2023 and from 1984–2023, respectively. Correlation skill has improved at all lead times in recent years, with the most noticeable improvements at longer lead times. While ten years is a relatively short sample size, improvements in both modeling and physical understanding should continue to result in future improvements in seasonal Atlantic hurricane forecast skill. More detailed verification statistics are also available at: https://tropical.colostate.edu/archive.html#verification

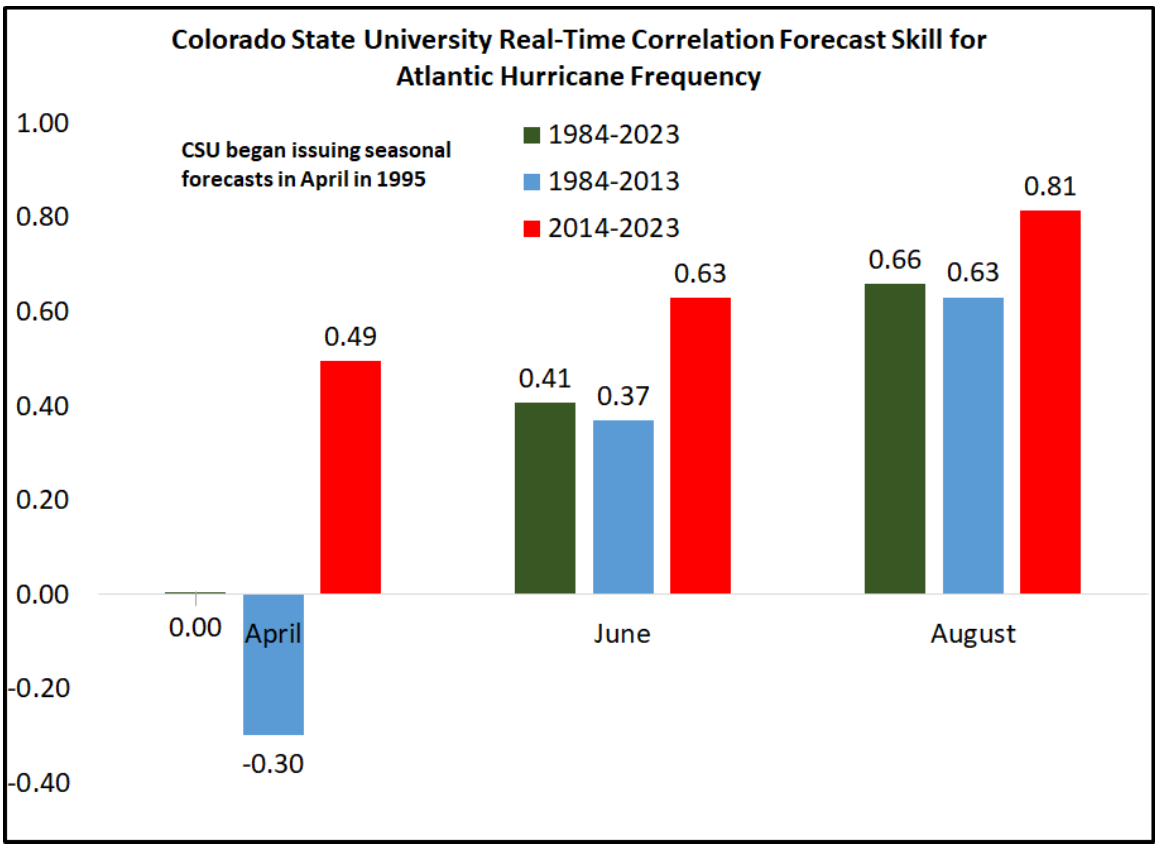


Figure 30: CSU's real-time forecast skill for Atlantic hurricanes using correlation as the skill metric. Correlation skills are displayed for three separate time periods: 1984–2013, 2014–2023 and 1984–2023, respectively.

https://www.hartenergy.com/exclusives/exclusive-liberty-ceo-say-world-needs-get-energy-sober-208674

Exclusive: Liberty CEO says World Needs to Get 'Energy Sober'

More money for the energy transition isn't meaningfully moving how energy is being produced and fossile fuels will continue to dominate, Liberty Energy Chairman and CEO Christ Wright said.

Jordan Blum   Hart Energy

Tue, 04/02/2024 - 03:34 PM

(*Source: Hart Energy.com*)

Jordan Blum, editorial director, Hart Energy: We are here at Hart Energy's DUG Gas+ Conference in Shreveport. I'm joined by Chris Wright, the founder, chairman and CEO of Liberty Energy. Thank you so much for joining us. Now, you were just giving a talk on energy, climate, poverty and prosperity. I know you could easily talk for an hour on the topic, but can I get you to just give the elevator pitch of why fossil fuels aren't going away anytime soon?

Chris Wright, chairman and CEO, Liberty Energy: Yeah. Even the title is a mouthful, but yeah, trying to cover a lot of complex stuff, but really just talking about what's actually happening with the energy system, how it's evolved over the last 200 years, how it evolved over the last 12 years. Different [from] what most people think, and then climate change, I think it's important to understand that a very real, a global phenomenon — technologies ultimately will solve this challenge, but we need to look at it realistically in what those trade-offs are. If you make energy more expensive, but you don't change greenhouse gases, you just impoverish people and you export industries. Too much of what we do today isn't good for humans, isn't really changing the energy system. It isn't doing anything positive for climate change. So my license plate is energy sober. My goal is to get the world more energy sober.

JB: Very good. We were talking a little bit, it's about following the money. Can I get you to talk about the challenges and successes of selling this vision to Wall Street investors?

CW: Yeah. Look, even from schools I speak in high schools or universities or in Wall Street, people want to know the truth. It just energy's complicated. So I haven't found a lot of pushback on people understanding, "Hey, okay, so that's actually how things are going." They aren't changing much, but they say, "But Chris, you're aware the money, there's more money in low carbon energy today than in hydrocarbons that power the world in investment capital." But it's not meaningfully moving how energy's produced. So to me, that's mal investment of capital, but that doesn't mean it's going to stop.

JB: Very good. Now, obviously emissions are a real challenge for the industry, but they're being addressed. I mean, how do you see the progress being made and what's more to do?

CW: Yes. I mean, look, 60% of the decline in emissions in the U.S. and we have larger and absolute terms decline in emissions than any country on earth. Most of the biggest component of that is just natural gas, mostly by market forces displacing coal in the power sector, because if you change things in hydrocarbons since they're large, you can have a big impact. So yes, getting natural gas as growing part of the energy system, producing oil and natural gas in cleaner and lower impact ways. Those are quite meaningful, and in fact, in the next decade or two, they're going to be the biggest movers in reducing greenhouse-gas emissions. But equally importantly, I would say more importantly is to reduce air pollution. So traditional biomass burning wood and dung indoors, burning coal in an uncontrolled way, uncontrolled for pollutants, not just greenhouse-gas emissions. Those are things we can address and we can affix as the world gets more. I think our number one goal should be clean air and more energy, and maybe the third goal is reduce greenhouse-gas emissions from that cleaner better energy.

JB: Very good. Now, obviously crude oil is not going away anytime soon, but there's maybe even more bullishness on long-term natural gas demand worldwide. Obviously, we're not hearing the phrase bridge fuel so much anymore. Can I kind of get you to elaborate there and compare and contrast?

CW: Yeah. As I spoke at DUG here today, the fastest growing energy source on the planet over the last 12 years is natural gas because it's a large fuel source already, and it's growing a little bit more than 2% a year. Oil is growing about 1% a year, but in absolute numbers, that's still a lot of growth. They're the first for natural gas and second for oil fastest growing energy source on the planet. I don't see any realistic prospects of those growth rates meaningfully changing in the next decade or two, but natural gas is the fastest growing fuel source. It's been great for this country. If we can build more infrastructure and export it more, we'll bring that slightly cleaner, slightly lower cost fuel to more and more locations around the world.

JB: Now focusing a little bit more on the here and now, we're in the Haynesville, prices are pretty weak right now. You all are pretty active in the basin. Of course. Can I get you to talk about just how you feel about current activity and prices, and where we go from here?

CW: Yeah. The problem in the natural gas industry is our companies here are too good. We're really good at producing natural gas and again, honestly too good. So we had, 15 years ago, we had 1,600 rigs drilling for natural gas, and we were the largest importer of natural gas in the world. Today we got a little more than a hundred rigs drilling, and we're the largest exporter. That means today before that export capacity comes on, pricing is lower and depressed. We're seeing gas activity contract, I think as it should. But a lot of new export capacity, they'll come on later this year and over the next couple years, we're also starting to see after 20 years of very low growth in demand for electricity, we're seeing that the next decade is going to see much faster growth in electricity demand. What's going to be the biggest source of supplying that growth in demand for electricity? I think it's a pretty safe bet it's going to be natural gas. So I think the outlook over the next five, 10 years for natural gas is quite bright, based on demand growth, but we're good at producing it. We're never going to have a thousand rigs running natural gas again, and that's evidence of success.

JB: Very good. Well, thank you so much for joining us here at DUG Gas+ in Shreveport. We really appreciate it. To read and watch more, please visit online at hartenergy.com.

Changes in EV Market

Slowing of EV Growth

EV growth slowing due to economic downturn, subsidy cuts, and lack of charging infrastructure

Global EV Demand Forecast

(Unit: Million)

EV Demand Forecast by Region

(Unit: Million)

	2024	2025	2026	2030	CAGR (2024~2030)
KR	**0.2**	**0.3**	**0.4**	**0.6**	+17%
YoY	+41%	+24%	+23%	+14%	
US	**2.2**	**3.3**	**4.2**	**8.4**	+25%
YoY	+74%	+49%	+27%	+13%	
EU	**3.2**	**4.6**	**5.9**	**10.4**	+22%
YoY	+42%	+42%	+29%	+10%	
CN	**6.6**	**8.4**	**10.4**	**16.2**	+16%
YoY	+29%	+27%	+23%	+9%	

HEV Lineup Reinforcement

- New HEV model launches
- +21% CAGR from 2024 to 2028

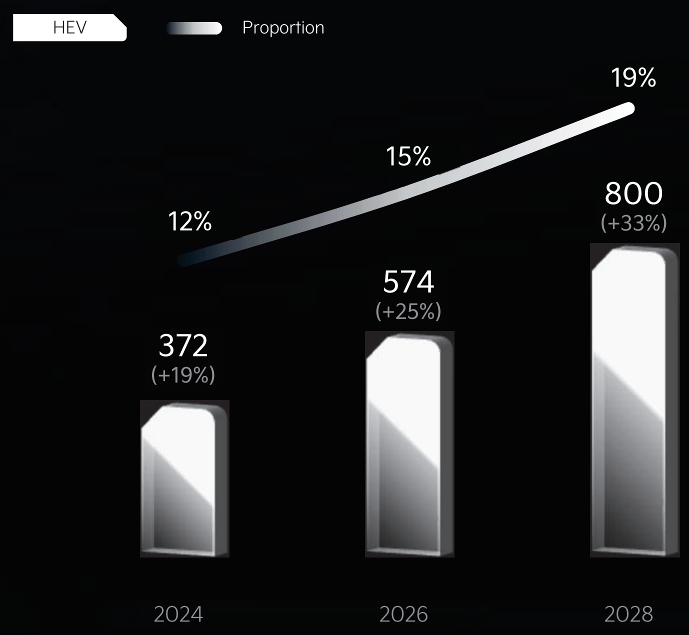
HEV Line-up

(Number of Models)

	2024	2026	2028
Passenger	2	2	2
SUV	4	6	7
Total	6	8	9

HEV Sales Contribution

(Unit: Thousand / % YoY)



- Key response strategies ❷ •

Mass EV Model Launch

Introducing new mass EV Models

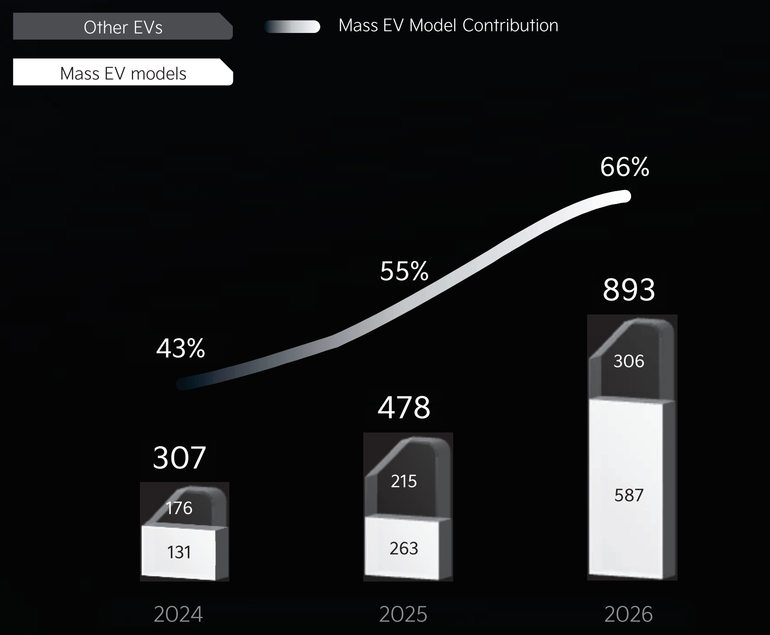
Mass EV Model Lineup

(Number of Models)

		2024	2025	2026
Major Markets	Dedicated EVs	1	4	4
	Derivative EVs	2	2	2
	Total	3	6	6
Emerging Markets	Dedicated EVs	2	4	4
	Derivative EVs	1	3	3
	Total	3	7	7

Mass Model Sales Contribution

(Unit: Thousand / %)



The Rise of Chinese Brands

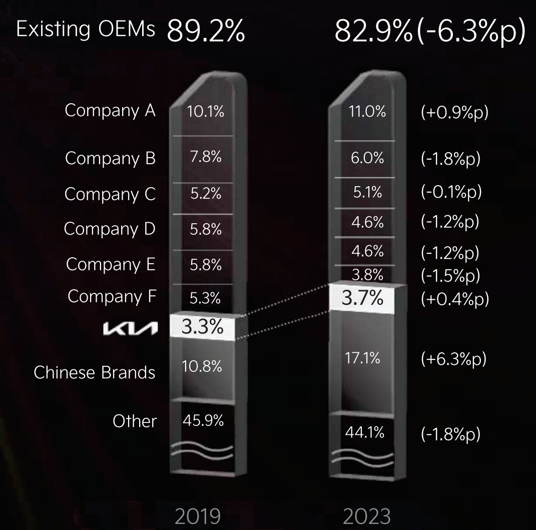
Led by Support Policy and Overseas Production Expansion

Chinese brands in 2023

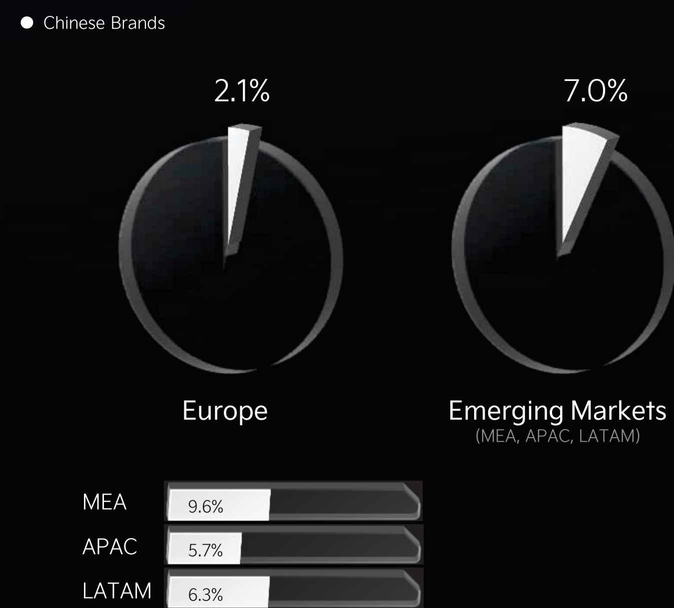
52.9% domestic market share (+12.6%p Vs. 2019) / 1.7 million units exported from China (+1.2M units Vs. 2019)

Market Share per Global Brand

Market share decrease across existing OEMs due to Chinese brand growth



2023 Chinese Brand Market Share by Region

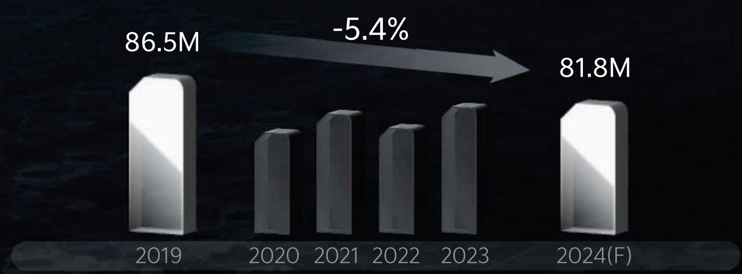


Decelerating Demand, Accelerating Competition

Intensifying Sales Competition and Slowing Demand Recovery

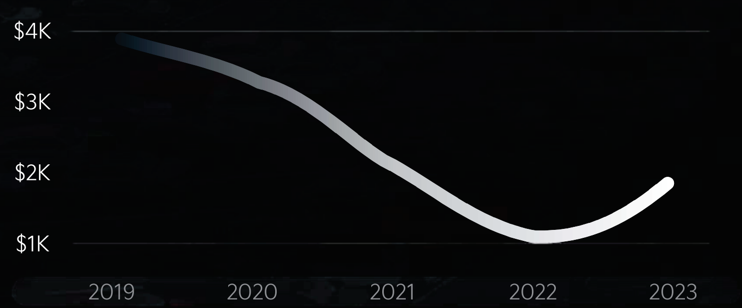
Limited demand recovery to pre-COVID
Increased inventories and incentive spending
Intensified EV price competition

Industry Demand

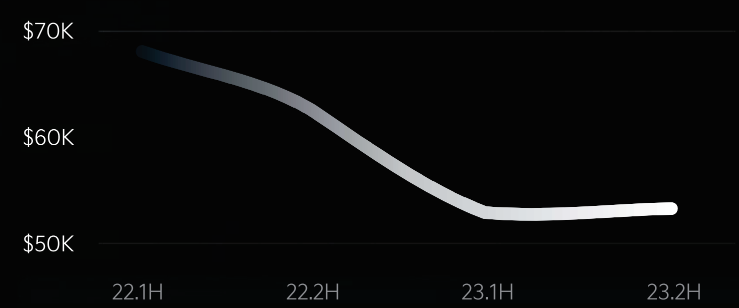


New Car Inventory (US)

Industrial Incentives (US)



Average EV Price (US)



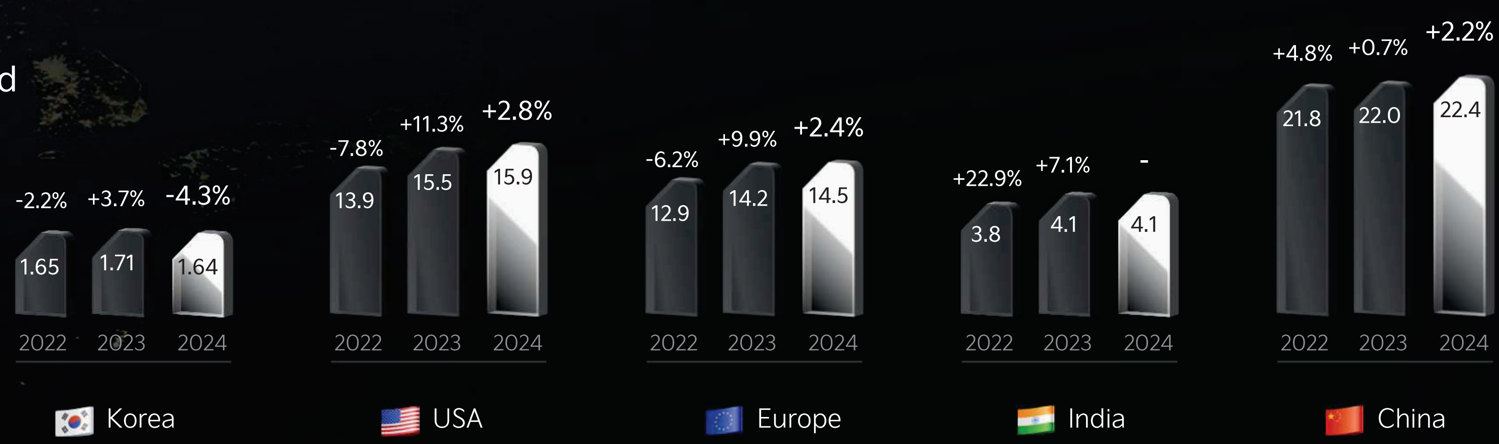
2024 Global Auto Demand

Global Demand

(Unit: YoY/Million)

2022	2023	2024
-2.5% 74.9mn	+7.6% 80.6mn	+1.5% 81.8mn

Industrial Demand By Region



Ford Updates EV, Hybrid Plans, Readies Manufacturing Plants

- Ford continues to invest in a broad set of EV programs as it works to build a full EV line-up. In parallel, Ford is expanding its hybrid electric vehicle offerings. By the end of the decade, the company expects to offer hybrid powertrains across its entire Ford Blue lineup in North America.

- Equipment installation is underway at the Tennessee Electric Vehicle Center assembly plant at BlueOval City, which aims to begin customer deliveries of Ford's next-generation electric truck in 2026

- Expansion progresses at Ohio Assembly Plant in Avon Lake, to produce an all-new electric commercial vehicle for Ford Pro customers beginning mid-decade; construction progressing at BlueOval Battery Park Michigan, and BlueOval SK joint venture battery plants in Tennessee and Kentucky

- Ford reiterates commitment to its Oakville, Ontario, assembly plant as the company retimes the launch of its all-new three-row electric vehicles to 2027

- Design work continues on future EVs, including a flexible small and affordable EV platform by a skunkworks team in California

DEARBORN, Mich., April 4, 2024 – Ford Motor Company said today it is retiming the launch of upcoming electric vehicles at its Oakville, Ontario, assembly plant while continuing to build out an advanced industrial system to produce its next-generation electric vehicles, including greenfield construction and conversion of existing assembly plants.

The company continues to invest in a broad set of EV programs as it works to build a full EV line-up. These initiatives support the development of a differentiated and profitably growing EV business over time while Ford serves customers with the right mix of gas, hybrid and electric vehicles based on demand today. In parallel, Ford is expanding its hybrid electric vehicle offerings. By the end of the decade, the company expects to offer hybrid powertrains across its entire Ford Blue lineup in North America. In the first quarter of 2024, Ford's electric vehicle sales increased by 86% and hybrid sales rose 42% versus a year ago.

"As the No. 2 EV brand in the U.S. for the past two years, we are committed to scaling a profitable EV business, using capital wisely and bringing to market the right gas, hybrid and fully electric vehicles at the right time," said Jim Farley, Ford president and CEO. "Our breakthrough, next-generation EVs will be new from the ground up and fully software enabled, with ever-improving digital experiences and a multitude of potential services."

Assembly plant in Oakville, Ontario

The transformation of Oakville Assembly Plant – a comprehensive overhaul of the plant from a gas vehicle assembly plant into an EV manufacturing complex – is set to begin in the second quarter, as planned.

Preparations continue for the market launch of Ford's all-new three row electric vehicles at the assembly complex in Oakville, Ontario, which the company said it will re-time to 2027 from 2025. The additional time will allow for the consumer market for three-row EVs to further develop and enable Ford to take advantage of emerging battery technology, with the goal to provide customers increased durability and better value.

"We value our Canadian teammates and appreciate that this delay will have an impact on this excellent team," Farley said. "We are fully committed to manufacturing in Canada and believe this decision will help us build a profitably growing business for the long term."

The company will work with Unifor to mitigate the impact the launch delay will have on its workforce at Oakville.

"We are committed to taking care of our valued Oakville employees through this transition," said Bev Goodman, president and CEO, Ford Canada. "While this change requires a revision to the timeline, it will support a viable and growing future for our company, employees and dealers."

BlueOval City

The creation of the BlueOval City campus – Ford's new advanced auto production complex that includes the Tennessee Electric Vehicle Center assembly plant – is progressing on track. In addition to paint shop and vehicle assembly equipment, installation is also underway for nearly 4,000 tons of stamping equipment that will produce the sheet metal stampings for Ford's next all-new electric truck.

Ford plans to begin customer deliveries of the new truck in 2026 and gradually ramp up production to help assure quality. The Tennessee Electric Vehicle Center will be Ford's first Industry 4.0 plant, combining automation and connectivity to help elevate quality and efficiency.

Prospective employees can meet with Ford representatives at the new Ford Tennessee Discovery Center in Brownsville, Tenn., once it opens. The plant's management team brings together strong leaders from around the world, including Ford veterans and talent from Tesla, Amazon, Meta, Toyota, FedEx and more. Community members also will be welcome to experience advanced manufacturing through virtual reality simulations at the Discovery Center.

Ohio Assembly Plant

Additionally, Ford continues its expansion of Ohio Assembly Plant in Avon Lake to produce an all-new electric commercial vehicle for Ford Pro customers beginning mid-decade.

Half of the structural steel is erected on the site, interior slabs are being poured, concrete walls are going up and masonry is beginning on interior walls. Ford expects to begin tool installation at Ohio Assembly Plant in spring 2025.

Employees at the plant, like at other Ford manufacturing facilities, will use wearable technology to support high-quality and efficient manufacturing.

Future EVs

Design work continues on Ford's future-generation EVs. A skunkworks team in California is developing a smaller, low-cost, profitable, flexible EV platform capable of underpinning multiple vehicles at high volumes. Alan Clarke leads the growing team, which includes personnel from Auto Motive Power (AMP) following Ford's acquisition of the EV energy management startup in late 2023.

In the meantime, construction is progressing at BlueOval Battery Park Michigan, in Marshall, Mich., and at the BlueOval SK joint venture battery plants in Tennessee and Kentucky.

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About Ford Motor Company

Ford Motor Company (NYSE: F) is a global company based in Dearborn, Michigan, committed to helping build a better world, where every person is free to move and pursue their dreams. The company's Ford+ plan for growth and value creation combines existing strengths, new capabilities and always-on relationships with customers to enrich experiences for customers and deepen their loyalty. Ford develops and delivers innovative, must-have Ford trucks, sport utility vehicles, commercial vans and cars and Lincoln luxury vehicles, along with connected services. The company does that through three customer-centered business segments: Ford Blue, engineering iconic gas-powered and hybrid vehicles; Ford Model e, inventing breakthrough EVs along with embedded software that defines exceptional digital experiences for all customers; and Ford Pro, helping commercial customers transform and expand their businesses with vehicles and services tailored to their needs. Additionally, Ford provides financial services through Ford Motor Credit Company. Ford employs about 177,000 people worldwide. More information about the company and its products and services is available at corporate.ford.com.

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A - John T. Lawler {BIO 17882934 <GO>}

Yeah, well, we definitely need to work to match capacity with demand. And demand is much lower than the industry expected when it comes to EVs. And when we look at that, prices came down dramatically. Growth is much less than what we thought. So we are right-sizing our capacity and the investments that we're putting into EVs. But it's not a matter of if, it's a matter of when.

And I think we're in the transition between the early adopters that were much more willing to deal with some of the ancillary items that come with EVs, charging range, and things like that. We're moving into the early majority. And the early majority is much less forgiving, and pricing is an issue. And one of the things we're finding and we realized this, and I think this was a benefit of being a first mover in the market. One of the first movers in the market is that we don't believe the game is going to be really fought in one with larger vehicles. We think it's going to be in the smaller, more affordable vehicles. And that's why we started the group out in California, which is a group of highly successful EV engineers, designing a new platform for us in a much different way. And it'll allow us to have that low-cost affordable EV platform where we can create multiple top hats off of that.

And I think that's where we're really going to start to see the traction because the real competition where we see it is the low-cost EVs from China, as well as Tesla. And so, we're working towards that future. Now, of course, we're going to have some large EVs as well, but they're going to be very limited in the scope and the number of top hats that we have. So we're thinking about it in that way. And one of the things about the segmentation that's different, clearly, is everybody gets to see exactly where we are in EVs.

There's no wondering what's happening with EVs with Ford, I'd say pure business, there are no credits in there for the greenhouse gas or the emissions that they provide for us, right? Every lightning allows us to sell twelve 150s.

And so -- but there's nothing numerical in there. There's nothing financial in there. So you see the pure business and the reason why we did that with the EV business is because eventually it has to stand on its own, right? It can't be there only to provide credits for your Blue and Pro business because eventually, it has to stand on its own. So that's how we're thinking about it, John. We think that the first real inflection point is going to come when some of the lower-priced EVs come online.

Q - John Murphy {BIO 5762430 <GO>}

So, I mean, we used to think -- I mean, and this is our faulty thinking, or maybe not. I don't. We'll Waltz and see how this works out is that if you came in with high-end, high-performance, high-priced EVs, that might work. And it seems like that there's a tiny part of the market. So that's actually maybe true, but it's small. So the small EVs might be a larger market, but I guess the question is, when you talk about a small vehicle, like does that mean Escape size? Does that mean sub-Escape size? What does that mean? Because Americans, whether it be an EV, a diesel, four-cylinder, whatever it may be, don't like small vehicles, right? And your business is predicated on these unbelievably great large trucks. So now you're talking about a small vehicle.

What does that mean? And does that mean that Ford is coming back into, maybe it's not. We'll see, is it a car and who are they kind of -- who you are going to supplant in that part of, part of the market? Because there's some pretty good competition on the ice side there. So I just curious, like what this really means. And there's some concern that, like this, this might be compliant and that you just answered the question that it could be a compliance vehicle.

That's not what you're saying. You're saying it's the exact opposite of that. But I mean, how does the American market work for a vehicle like this?

A - John T. Lawler {BIO 17882934 <GO>}

Yeah, I think so you have to start to unpack what an EV is and what an EV isn't from a standpoint of, as Doug explains, the physics around the size and the battery. In the conventional internal combustion business, the larger the vehicle, the more margin there was, because the cost to add from the size is much less than the value of the consumer, right?

The marginal utility of the vehicle. The third row, the ability to tow more, the ability to haul more, and so the margin goes up. It's the exact opposite with EVs because the bigger the vehicle, the bigger the battery. And the battery is the most expensive thing in the vehicle. And then the bigger the battery, the more weight, the more battery you need, the less efficient the vehicle is. So the costs just spiral out of control, which is the exact opposite to what internal combustion vehicle does, a gas or a diesel.

So it's about that smaller platform. Now, the great thing about EVs is when you look at the design footprint, the way you can think about it is that the exterior size of an Escape could be the interior size of an Explorer because you don't have the package limitations of the front, right?

And so there's a lot of degrees of freedom when -- especially when you're designing it with a new platform, with individuals that are on their third or fourth platform of EVs that they're designing. And the way they do it is allowing us to create a platform that we believe is going to be able to cover a large segment of the population and give them the needs through different top hats on that platform. So that's how we're thinking about it.

And I know it's a little bit opaque because we haven't introduced the vehicle. And, you know, we need a little bit more time before we do that. But I think there's a lot of opportunity there to take the benefits of an EV and meet the consumers' needs with a smaller platform type that requires less of a battery, which then brings the affordability down.

Q - John Murphy {BIO 5762430 <GO>}

Okay, I'm going to ask you a follow-up to that. And you want to say, hey, listen, we just can't answer because we're not talking about it yet. I think you said the footprint of Escape with the interior of an Explorer.

A - John T. Lawler {BIO 17882934 <GO>}

Yeah.

Q - John Murphy {BIO 5762430 <GO>}

Okay. All right. So that means that changes the game, right? Because the Explorer as you take almost the heart of the US market. If you can give it to somebody in that performance range, they would lap it up all day long.

A - John T. Lawler {BIO 17882934 <GO>}

Yeah. And so you think about it, you could probably do the footprint of an Explorer with the interior of an Expedition. I think it's basically it's not exact, but it's almost one size from the exterior to the interior degree of freedom that you can do with an EV.

Q - John Murphy {BIO 5762430 <GO>}

So this is not recreating the Pinto. This is recreating an Escape size, size exterior with a big interior?

A - John T. Lawler {BIO 17882934 <GO>}

Yeah. It could be an SUV, it could be a truck, it could be a van. It could be a lot of different things.

Q - John Murphy {BIO 5762430 <GO>}

Now, I guess you guys have talked about that vehicle coming out in 2025. I think that's what the statements have been. Is that something where it would be revealed in 2025 or SOP would be 2025 or is that still TBD?

A - John T. Lawler {BIO 17882934 <GO>}

That's still TBD.

Q - John Murphy {BIO 5762430 <GO>}

Okay. And if we think about the gen one product being essentially Mach-E, gen two, and then gen three, which you guys have talked about, is this vehicle is separate from that development process?

A - John T. Lawler {BIO 17882934 <GO>}

Yeah. So hopefully I can clarify this without adding confusion. So check me on it. So gen one, of course, was the lightning, the Mach-E in the transit van, right? The e-van, e-transit van. So gen two, we've been talking about gen two, but I don't think we can think about it as gen two. I think it's our next EV platforms. And there's one that is the ground up pickup and then the potential to have other vehicles off that platform.

And then there is the small platform that we're developing. And I wouldn't think about them as gen two or gen three. I'd just say it's our next generation platforms, and one's a larger platform and one's a smaller platform.

Q - John Murphy {BIO 5762430 <GO>}

Got it. Okay, so the (Technical Difficulty) the coming of gen two. Okay. Is the same group making the ground-up pickup to the small platform, or is it?

A - John T. Lawler {BIO 17882934 <GO>}

No. The small platform is a group of individuals. We call it our skunkworks in California, led by Alan Clarke, who came from Tesla. And it's a group of individuals that he's recruited into the company to develop this platform in a different way.

And I think that's important to understand because cost is critical on this platform, and it's the next leap forward in the design and how you design, manufacture, and develop an electric vehicle platform.

Q - John Murphy {BIO 5762430 <GO>}

Exciting. So it sounds like there's a greater recognition. It's the full package as opposed to just a hyper-focus just on the battery, right? Than it's (Multiple Speakers). It is the total vehicle integration?

A - John T. Lawler {BIO 17882934 <GO>}

It is the total vehicle integration, complete systems design. Not a waterfall process, an agile process, completely different design process from what traditional OEMs have designed -- have used to design vehicles over the years.

And there's a thought out there about how are the Chinese able to design their electric vehicles so quickly relative to what the traditional OEMs are taking? It's a different approach. It's an agile approach. It's not the traditional waterfall approach that we've had for decades. And Alan and his team are using that type of approach to design this vehicle.

Q - John Murphy {BIO 5762430 <GO>}

So if you think about those products, I mean, is this an acceptance that battery technology might not make breakthroughs? Or, I mean, how do you think about sort of the potential for battery product -- battery technology in the context of this? I mean, we had quantum scape on there, and they sound like they have some really interesting things. Not to say it's going to be solid state, but how do you think about the technological breakthroughs in batteries on costs, efficiency, and it's all kind of intertwined to make the future of EVs work for Ford?

A - John T. Lawler {BIO 17882934 <GO>}

That's going to have to continue. It's got to be a core part of it. The battery technology is going to have to advance, especially when you start to get into advanced duty cycles, right? You can' -- the technologies that exist today are not going to allow you to put a battery in a vehicle that has a high towing duty cycle.

It's just not going to work. The battery will have to be too big. So there's going to have to be advances in the technology, and that'll cascade down and that'll be available to smaller vehicles.

But then that'll help drive down cost in the future because less battery, more efficiency, quicker charge times, et cetera.

Q - John Murphy {BIO 5762430 <GO>}

And when you think about getting to breakeven or potentially the -- I think the ultimate target of mid to high single digit EBIT profit margins on gen two products, I don't know if you can give us sort of an idea of volumes to get there, time frame to get there.

What drives the $5.5 billion losses to something that would be nice? Good, positive profit generation?

A - John T. Lawler {BIO 17882934 <GO>}

Yeah. Hurdling all the time.

Q - John Murphy {BIO 5762430 <GO>}

Yeah. The way we are, hopefully. Yeah.

A - John T. Lawler {BIO 17882934 <GO>}

Yeah.

Q - John Murphy {BIO 5762430 <GO>}

We had Edwin Moses to clear the hurdle, but, I mean, this is going to have to be real.

A - John T. Lawler {BIO 17882934 <GO>}

Yeah. So it has to be real. And some would say we're exposed because you can see exactly where we're at and the progress that we're going to make. But I think, some might say that's a bad thing. I think the transparency is a good thing, especially for our investors. So battery technology is a big part of it and advances in battery technology, but then again, it's the integrated system design, and it's the complete process that we're using from a ground-up standpoint.

And so although the group in California is designing the platform separate from the larger vehicle platform, remember, Doug's in charge of both.

Q - John Murphy {BIO 5762430 <GO>}

Yeah, yeah, yeah.

A - John T. Lawler {BIO 17882934 <GO>}

Right. And so Doug is leading both of those, and he's bringing as much back into our larger platform that the next lightning pickup truck will be on or pickup truck will be on. I don't know that it's going to be called lightning. So now I'm getting out of my comfort zone there. So no one says it's the next lightning, it's the next pickup truck. But, yeah, John, it absolutely has to be breakthroughs from a battery standpoint, from the ground up design, moving into a more efficient design, less complexity.

And then, of course, the electrical architecture is going to play a role in that and providing more advanced interface from that standpoint, the ability to provide services and experiences, improving the manufacturing ability of the vehicle, designing better for manufacturing. So all of those things are coming into play to improve the margins. And as I said earlier, the most important thing is the EV business.

Model E has to stand on its own. It has to get there, and it's going to be through these next generations that will get to those points, or we are not going to move forward and we said that.

Q - John Murphy {BIO 5762430 <GO>}

Is there any potential that you would tag on to that high to mid-single-digit EBIT margin incremental services and post-sale -- sales in profit to get to that adequate margin in return for Model E in a way that you're not currently doing it for Ford Blue? And assuming you have a higher attach with those kinds of consumers in that kind of product?

A - John T. Lawler {BIO 17882934 <GO>}

So there is services, revenue and margin assumes but I wouldn't say that, in that time period that we're assuming it's going to be that much different than what we'd see on the Blue side.

Q - John Murphy {BIO 5762430 <GO>}

Got it. IRA, we didn't even ask about that yet, and we're talking about Model E. What is your -- I mean, what is your take on how good that is for Ford at the moment as far as you're making these EVs more affordable And what do you think the risk is and how would the business shift if consumer incentives were somehow canceled post-November election? Maybe utilization out of it, if these got rolled back for whatever reason they got, they got rolled back, how impactful do you think that would be in the way you think about development Model E here in North America?

A - John T. Lawler {BIO 17882934 <GO>}

Yeah, so, I think first of all, we think that the probability that there could be rolled back quickly is relatively low. But never say never. Clearly, it's going to add to an affordability issue for consumers. And so it's going to put more pressure on the business. But that's why, I think you know the ramp and what we're seeing as far as the rollout is important from the standpoint of the technologies and the efficiencies that we need to bring forward.

So, it's just another reason why it's important that in our next-gen and then the generation after that, we're continuing to drive those new technologies from better standpoint, the efficiencies et cetera. Because eventually, they do roll off, right? And as the business needs to stand on its own. So it's going to come down to affordability and if they were to go away, that's going to be the issue is either the advance is going to come down because the price is going to have to is going to be higher or the OEMs are going to have to find offsets.

Q - John Murphy {BIO 5762430 <GO>}

And the change in the EPA revision in these final rules that we'll see what final in a year or two ratings shift, right? There is nothing final unfortunately from the regulatory front, which I feel for you guys to that makes it very difficult to run and run the business and allocate capital. But based on what you know right now, does that glide path match more what you think is going to -- going on in the market and allow you to operate the business more efficiently and more directed at what's happening in the market as opposed to have to meet some onerous near-term regulations. Tough in the long-term, but I mean, it gives you a little bit of breathing room here in the near-term?

A - John T. Lawler {BIO 17882934 <GO>}

Yeah, they're ambitious in challenging I would say that. That's for sure. But I do think that EPA has been working with us to better construct the ramp for those consistent with how we're seeing EVs come in and what we're seeing in the marketplace. But by no means, they are ambitious and challenging. But one of the things that is important for us is that we continue to have hybrid technologies. We continue to invest in them. We've been building hybrids for 20 years.

And we never pulled back from them. And we see that as an important part of that bridge and that transition over the next, let's say, five years. As we move through the rest of the decade of how you meet that compliance. But we're going to continue to provide HEVs, plug-in hybrids, battery-electric vehicles, exciting products where our customers are going to love that will allow us to meet those requirements.

Q - John Murphy {BIO 5762430 <GO>}

Competitive landscape is shifting quite a bit. Chinese vehicles were net exported 2.6 million units last year, three years prior essentially none. So not only you are facing great competition in the domestic market in China. You starting to face these companies and these vehicles are around the world. How do you keep up with them,

Executive summary

Electric car sales break new records with momentum expected to continue through 2023

Electric car markets are seeing exponential growth as sales exceeded 10 million in 2022. A total of 14% of all new cars sold were electric in 2022, up from around 9% in 2021 and less than 5% in 2020. Three markets dominated global sales. China was the frontrunner once again, accounting for around 60% of global electric car sales. More than half of the electric cars on roads worldwide are now in China and the country has already exceeded its 2025 target for new energy vehicle sales. In Europe, the second largest market, electric car sales increased by over 15% in 2022, meaning that more than one in every five cars sold was electric. Electric car sales in the United States – the third largest market – increased 55% in 2022, reaching a sales share of 8%.

Electric car sales are expected to continue strongly through 2023. Over 2.3 million electric cars were sold in the first quarter, about 25% more than in the same period last year. We currently expect to see 14 million in sales by the end of 2023, representing a 35% year-on-year increase with new purchases accelerating in the second half of this year. As a result, electric cars could account for 18% of total car sales across the full calendar year. National policies and incentives will help bolster sales, while a return to the exceptionally high oil prices seen last year could further motivate prospective buyers.

There are promising signs for emerging electric vehicle (EV) markets, albeit from a small base. Electric car sales are generally low outside the major markets, but 2022 was a growth year in India, Thailand and Indonesia. Collectively, sales of electric cars in these countries more than tripled compared to 2021, reaching 80 000. For Thailand, the share of electric cars in total sales came in at slightly over 3% in 2022, while both India and Indonesia averaged around 1.5% last year. In India, EV and component manufacturing is ramping up, supported by the government's USD 3.2 billion incentive programme that has attracted investments totalling USD 8.3 billion. Thailand and Indonesia are also strengthening their policy support schemes, potentially providing valuable experience for other emerging market economies seeking to foster EV adoption.

Landmark EV policies are driving the outlook for EVs closer to climate ambitions

Market trends and policy efforts in major car markets are supporting a bright outlook for EV sales. Under the IEA Stated Policies Scenario (STEPS), the global outlook for the share of electric car sales based on existing policies and firm objectives has increased to 35% in 2030, up from less than 25% in the previous outlook. In the projections, China retains its position as the largest market for electric cars with 40% of total sales by 2030 in the STEPS. The United States doubles its market share to 20% by the end of the decade as recent policy announcements drive demand, while Europe maintains its current 25% share.

Projected demand for electric cars in major car markets will have profound implications on energy markets and climate goals in the current policy environment. Based on existing policies, oil demand from road transport is projected to peak around 2025 in the STEPS, with the amount of oil displaced by electric vehicles exceeding 5 million barrels per day in 2030. In the STEPS, emissions of around 700 Mt CO_2-equivalents are avoided by the use of electric cars in 2030.

The European Union and the United States have passed legislation to match their electrification ambitions. The European Union adopted new CO_2 standards for cars and vans that are aligned with the 2030 goals set out in the Fit for 55 package. In the United States, the Inflation Reduction Act (IRA), combined with adoption of California's Advanced Clean Cars II rule by a number of states, could deliver a 50% market share for electric cars in 2030, in line with the national target. The implementation of the recently proposed emissions standards from the US Environmental Protection Agency is set to further increase this share.

Battery manufacturing continues to expand, encouraged by the outlook for EVs. As of March 2023, announcements on battery manufacturing capacity delivered by 2030 are more than sufficient to meet the demand implied by government pledges and would even be able to cover the demand for electric vehicles in the Net Zero Emissions by 2050 Scenario. It is therefore well possible that higher shares of sales are achievable for electric cars than those anticipated on the basis of current government policy and national targets.

As spending and competition increase, a growing number of more affordable models come to market

Global spending on electric cars exceeded USD 425 billion in 2022, up 50% relative to 2021. Only 10% of the spending can be attributed to government support, the remainder was from consumers. Investors have also maintained confidence in EVs, with the stocks of EV-related companies consistently outperforming traditional carmakers since 2019. Venture capital investments in start-up firms developing EV and battery technologies have also boomed, reaching nearly USD 2.1 billion in 2022, up 30% relative to 2021, with investments increasing in batteries and critical minerals.

SUVs and large cars dominate available electric car options in 2022. They account for 60% of available BEV options in China and Europe and an even greater share in the United States, similar to the trend towards SUVs seen in internal combustion engine (ICE) car markets. In 2022, ICE SUVs emitted over 1 Gt CO_2, far greater than the 80 Mt net emissions reductions from the electric vehicle fleet that year. Battery electric SUVs often have batteries that are two- to three-times larger than small cars, requiring more critical minerals. However, last year electric SUVs resulted in the displacement of over 150 000 barrels of oil consumption per day and avoided the associated tailpipe emissions that would have been generated through burning the fuel in combustion engines.

The electric car market is increasingly competitive. A growing number of new entrants, primarily from China but also from other emerging markets, are offering more affordable models. Major incumbent carmakers are increasing ambition as well, especially in Europe, and 2022-2023 saw another series of important EV announcements: fully electric fleets, cheaper cars, greater investment, and vertical integration with battery-making and critical minerals.

Consumers can choose from an increasing number of options for electric cars. The number of available electric car models reached 500 in 2022, more than double the options available in 2018. However, outside of China, there is a need for original equipment manufacturers (OEMs) to offer affordable, competitively priced options in order to enable mass adoption of EVs. Today's level of available electric car models is still significantly lower than the number of ICE options on the market, but the number of ICE models available has been steadily decreasing since its peak in the mid-2010s.

Focus expands to electrification of more vehicle segments as electric cars surge ahead

Electrification of road transport goes beyond cars. Two or three-wheelers are the most electrified market segment today; in emerging markets and developing economies, they outnumber cars. Over half of India's three-wheeler registrations in 2022 were electric, demonstrating their growing popularity due to government incentives and lower lifecycle costs compared with conventional models, especially in the context of higher fuel prices. In many developing economies, two/three-wheelers offer an affordable way to get access to mobility, meaning their electrification is important to support sustainable development.

The commercial vehicle stock is also seeing increasing electrification. Electric light commercial vehicle (LCV) sales worldwide increased by more than 90% in 2022 to more than 310 000 vehicles, even as overall LCV sales declined by nearly 15%. In 2022, nearly 66 000 electric buses and 60 000 medium- and heavy-duty trucks were sold worldwide, representing about 4.5% of all bus sales and 1.2% of truck sales. Where governments have committed to reduce emissions from public transport, such as in dense urban areas, electric bus sales reached even higher shares; in Finland, for example, electric bus sales accounted for over 65% in 2022.

Ambition with respect to electrifying heavy-duty vehicles is growing. In 2022, around 220 electric heavy-duty vehicle models entered the market, bringing the total to over 800 models offered by well over 100 OEMs. A total of 27 governments have pledged to achieve 100% ZEV bus and truck sales by 2040 and both the United States and European Union have also proposed stronger emissions standards for heavy-duty vehicles.

EV supply chains and batteries gain greater prominence in policy-making

The increase in demand for electric vehicles is driving demand for batteries and related critical minerals. Automotive lithium-ion (Li-ion) battery demand increased by about 65% to 550 GWh in 2022, from about 330 GWh in 2021, primarily as a result of growth in electric passenger car sales. In 2022, about 60% of lithium, 30% of cobalt and 10% of nickel demand was for EV batteries. Only five years prior, these shares were around 15%, 10% and 2%, respectively. Reducing the need for critical materials will be important for supply chain sustainability, resilience and security, especially given recent price developments for battery material.

New alternatives to conventional lithium-ion are on the rise. The share of lithium-iron-phosphate (LFP) chemistries reached its highest point ever, driven primarily by China: around 95% of the LFP batteries for electric LDVs went into vehicles produced in China. Supply chains for (lithium-free) sodium-ion batteries are also being established, with over 100 GWh of manufacturing capacity either currently operating or announced, almost all in China.

The EV supply chain is expanding, but manufacturing remains highly concentrated in certain regions, with China being the main player in battery and EV component trade. In 2022, 35% of exported electric cars came from China, compared with 25% in 2021. Europe is China's largest trade partner for both electric cars and their batteries. In 2022, the share of electric cars manufactured in China and sold in the European market increased to 16%, up from about 11% in 2021.

EV supply chains are increasingly at the forefront of EV-related policy-making to build resilience through diversification. The Net Zero Industry Act, proposed by the European Union in March 2023, aims for nearly 90% of the European Union's annual battery demand to be met by EU battery manufacturers, with a manufacturing capacity of at least 550 GWh in 2030. Similarly, India aims to boost domestic manufacturing of electric vehicles and batteries through Production Linked Incentive (PLI) schemes. In the United States, the Inflation Reduction Act emphasises the strengthening of domestic supply chains for EVs, EV batteries and battery minerals, laid out in the criteria to qualify for clean vehicle tax credits. As a result, between August 2022 and March 2023, major EV and battery makers announced cumulative post-IRA investments of at least USD 52 billion in North American EV supply chains – of which 50% is for battery manufacturing, and about 20% each for battery components and EV manufacturing.

Trends and developments in EV markets

Electric light-duty vehicles

Electric car sales continue to increase, led by China

Electric car sales [1] saw another record year in 2022, despite supply chain disruptions, macro-economic and geopolitical uncertainty, and high commodity and energy prices. The growth in electric car sales took place in the context of globally contracting car markets: total car sales in 2022 dipped by 3% relative to 2021. Electric car sales – including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) – exceeded 10 million last year, up 55% relative to 2021.[2] This figure – 10 million EV sales worldwide – exceeds the total number of cars sold across the entire European Union (about 9.5 million vehicles) and is nearly half of the total number of cars sold in China in 2022. In the course of just five years, from 2017 to 2022, EV sales jumped from around 1 million to more than 10 million. It previously took five years from 2012 to 2017 for EV sales to grow from 100 000 to 1 million, underscoring the exponential nature of EV sales growth. The share of electric cars in total car sales jumped from 9% in 2021 to 14% in 2022, more than 10 times their share in 2017.

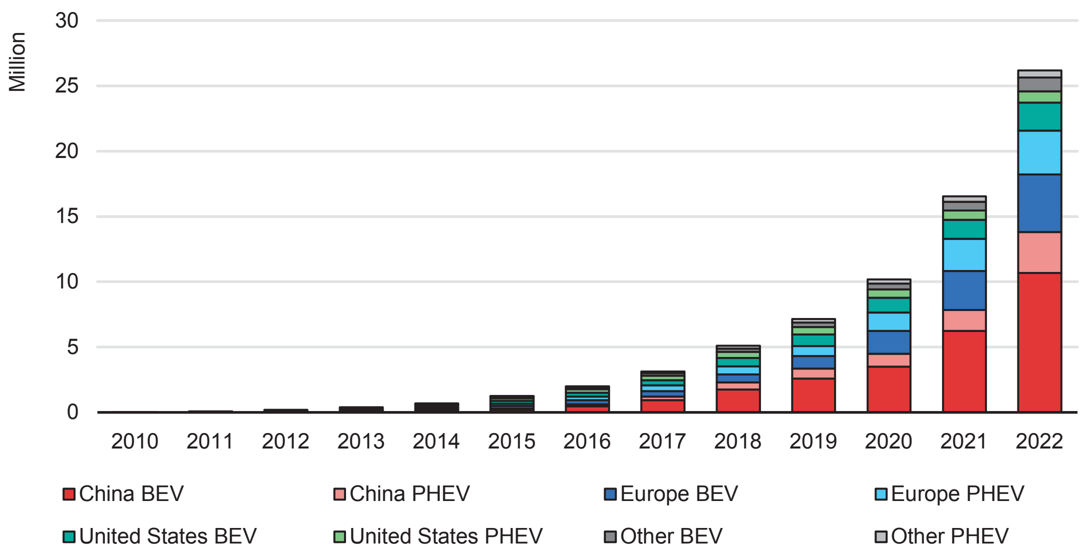
Over 26 million electric cars were on the road in 2022, up 60% relative to 2021 and more than 5 times the stock in 2018

Increasing sales pushed the total number of electric cars on the world's roads to 26 million, up 60% relative to 2021, with BEVs accounting for over 70% of total annual growth, as in previous years. As a result, about 70% of the global stock of electric cars in 2022 were BEVs. The increase in sales from 2021 to 2022 was just as high as from 2020 to 2021 in absolute terms – up 3.5 million – but relative growth was lower (sales doubled from 2020 to 2021). The exceptional boom in 2021 may be explained by EV markets catching up in the wake of the coronavirus

[1] The term sales, as used in this report, represents an estimate of the number of new vehicles hitting the roads. Where possible, data on new vehicle registrations is used. In some cases, however, only data on retail sales (such as sales from a dealership) are available. See Box 1.2 for further details. The term car is used to represent passenger light-duty vehicles and includes cars of different sizes, sports utility-vehicles and light trucks.
[2] Unless otherwise specified, the term electric vehicle is used to refer to both battery electric and plug-in hybrid electric vehicles but does not include fuel cell electric vehicles. For a brief description of the trends related to fuel cell electric vehicles, see Box 1.3.

(Covid-19) pandemic. Seen in comparison to recent years, the annual growth rate for electric car sales in 2022 was similar to the average rate over 2015-2018, and the annual growth rate for the global stock of electric cars in 2022 was similar to that of 2021 and over the 2015-2018 period, showing a robust recovery of EV market expansion to pre-pandemic pace.

Figure 1.1 Global electric car stock in selected regions, 2010-2022



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Electric car stock in this figure refers to passenger light-duty vehicles. In "Europe", European Union countries, Norway, and the United Kingdom account for over 95% of the EV stock in 2022; the total also includes Iceland, Israel, Switzerland and Türkiye. Main markets in "Other" include Australia, Brazil, Canada, Chile, Mexico, India, Indonesia, Japan, Malaysia, New Zealand, South Africa, Korea and Thailand.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: IEA analysis based on country submissions, ACEA, EAFO, EV Volumes and Marklines.

Over 26 million electric cars were on the road in 2022, up 60% relative to 2021 and more than five times the stock in 2018.

Half of the world's electric cars are in China

The increase in electric car sales varied across regions and powertrains, but remains dominated by the People's Republic of China (hereafter "China"). In 2022, BEV sales in China increased by 60% relative to 2021 to reach 4.4 million, and PHEV sales nearly tripled to 1.5 million. The faster growth in PHEV sales relative to BEVs warrants further examination in the coming years, as PHEV sales still remain lower overall and could be catching up on the post-Covid-19 boom only now; BEV sales in China tripled from 2020 to 2021 after moderate growth over 2018-2020. Electric car sales increased even while total car sales dipped by 3% in 2022 relative to 2021.

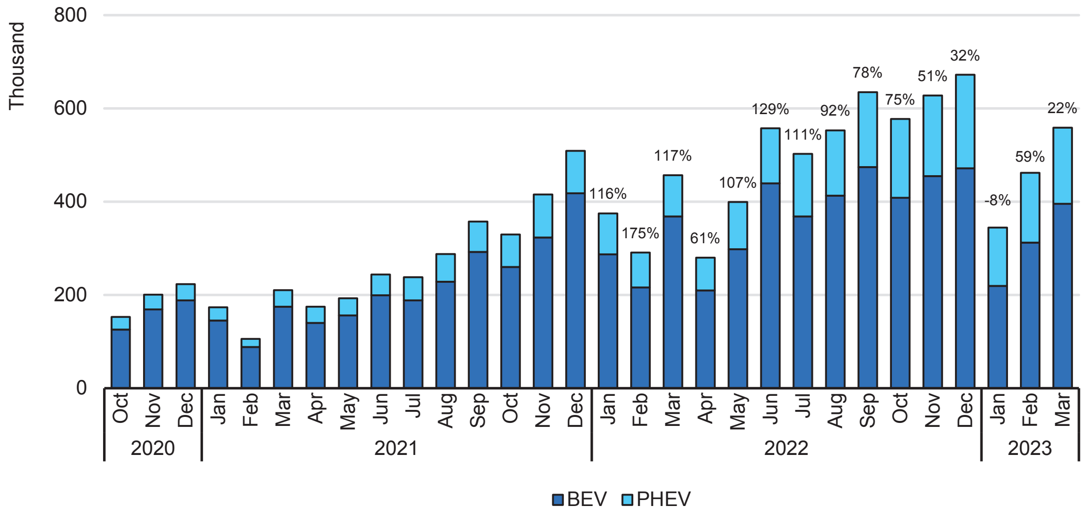
China accounted for nearly 60% of all new electric car registrations globally. For the first time in 2022, China accounted for more than 50% of all the electric cars on the world's roads, a total of 13.8 million. This strong growth results from more than a decade of sustained policy support for early adopters, including an extension of purchase incentives initially planned for phase-out in 2020 to the end of 2022 due to Covid-19, in addition to non-financial support such as rapid roll-out of charging infrastructure and stringent registration policies for non-electric cars.

In 2022, the share of electric cars in total domestic car sales reached 29% in China, up from 16% in 2021 and under 6% between 2018 and 2020. China has therefore achieved its 2025 national target of a 20% sales share for so-called new energy vehicles (NEVs)[3] well in advance. All indicators point to further growth: although the national NEV sales target is yet to be updated by China's Ministry of Industry and Information Technology (MIIT), which is responsible for the automotive industry, the objective of greater road transport electrification is re-affirmed in multiple strategy documents. China aims to reach a 50% sales share by 2030 in so-called "key air pollution control regions", and 40% across the country by 2030 to support the national action plan for carbon peaking. If recent market trends continue, China's 2030 targets may also be reached ahead of time. Provincial governments are also supporting adoption of NEVs, with 18 provinces to date having set NEV targets.

Support at the regional level in China has also helped to advance some of the world's largest EV makers. Shenzhen-based BYD has supplied most of the city's electric buses and taxis, and its leading position is also reflected in Shenzhen's ambition of reaching a 60% NEV sales share by 2025. Guangzhou, which has a 50% NEV sales share by 2025 target, facilitated the expansion of Xpeng Motors to become one of the national EV frontrunners.

[3] NEVs (China) include BEVs, PHEVs and fuel cell electric vehicles.

Figure 1.2 Monthly new electric car registrations in China, 2020-2023



Note: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Percentage labels in 2022-2023 refer to year-on-year growth rates relative to the same month in the previous year.
Source: IEA analysis based on EV Volumes.

Electric car sales in China have been steadily increasing since 2020, but future trends will warrant further examination given that purchase incentives ended in 2022.

Whether China's electric car sales share will remain significantly above the 20% target in 2023 remains uncertain, as sales may have been especially high in anticipation of incentives being phased out at the end of 2022. Sales in January 2023 plunged, and while this is in part due to the timing of the Chinese New Year, they were nearly 10% lower than sales in January 2022. However, electric car sales caught up in February and March 2023, standing nearly 60% above sales in February 2022 and more than 25% above sales in March 2022, thereby bringing sales in the first quarter of 2023 more than 20% higher than in the first quarter of 2022.

Growth remained steady in Europe despite disruptions

In Europe,[4] electric car sales increased by more than 15% in 2022 relative to 2021 to reach 2.7 million. Sales grew more quickly in previous years: annual growth stood at more than 65% in 2021 and averaged 40% over 2017-2019. In 2022, BEV sales rose by 30% relative to 2021 (compared to 65% growth in 2021 relative to 2020) while PHEV sales dipped by around 3%. Europe accounted for 10% of global growth in new electric car sales. Despite slower growth in 2022, electric car

[4] Europe includes European Union countries, Iceland, Israel, Norway, Switzerland, Türkiye, and the United Kingdom.

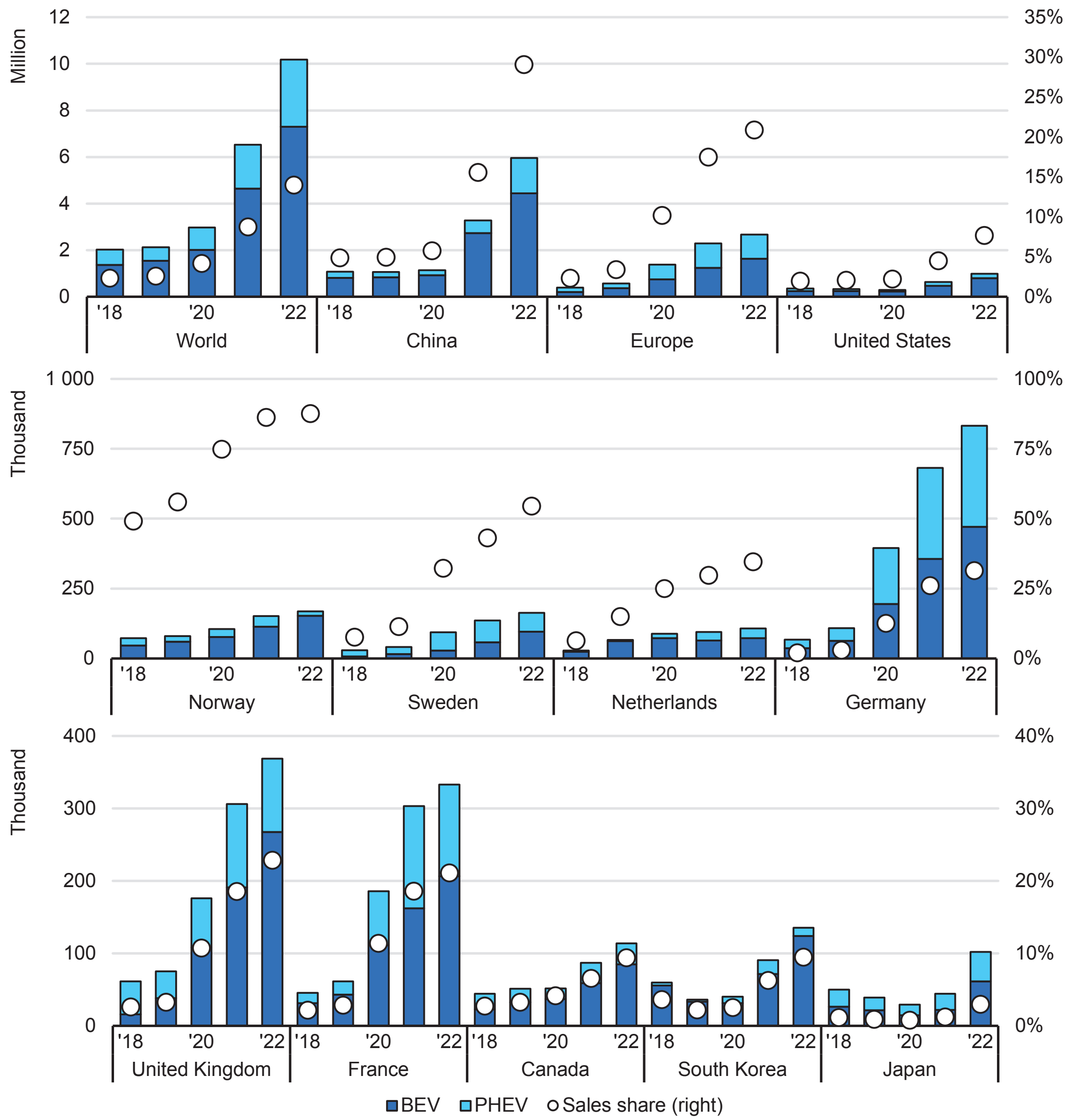
sales are still increasing in Europe in the context of continued contraction in car markets: total car sales in Europe dipped by 3% in 2022 relative to 2021.

The slowdown seen in Europe relative to previous years was, in part, a reflection of the exceptional growth in electric car sales that took place in 2020 and 2021 in the European Union, as manufacturers quickly adjusted corporate strategy to comply with the CO_2 emission standards passed in 2019. These standards covered the 2020-2024 period, with EU-wide emission targets becoming stricter only from 2025 and 2030 onwards.

High energy prices in 2022 had a mixed impact on the competitiveness of EVs relative to internal combustion engine (ICE) cars. Gasoline and diesel prices for ICE cars spiked, but residential electricity tariffs (with relevance for charging) also increased in some cases. Higher electricity and gas prices also increased manufacturing costs for both ICE and EV cars, with some carmakers arguing that high energy prices could restrict future investment for new battery manufacturing capacity.

Europe remained the world's second largest market for electric cars after China in 2022, accounting for 25% of all electric car sales and 30% of the global stock. The sales share of electric cars reached 21%, up from 18% in 2021, 10% in 2020 and under 3% prior to 2019. European countries continued to rank highly for the sales share of electric cars, led by Norway at 88%, Sweden at 54%, the Netherlands at 35%, Germany at 31%, the United Kingdom at 23% and France at 21% in 2022. In volume terms, Germany is the biggest market in Europe with sales of 830 000 in 2022, followed by the United Kingdom with 370 000 and France with 330 000. Sales also exceeded 80 000 in Spain. The share of electric cars in total car sales has increased tenfold in Germany since before the Covid-19 pandemic, which can in part be explained by increasing support post-pandemic, such as purchase incentives through the Umweltbonus, and a frontloading of sales in 2022 in expectation of subsidies being further reduced from 2023 onwards. However, in Italy, electric car sales decreased from 140 000 in 2021 to 115 000 in 2022, and they also decreased or stagnated in Austria, Denmark and Finland.

Figure 1.3 Electric car registrations and sales share in selected countries and regions, 2018-2022



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Passenger light-duty vehicles only. Major markets at the top. Other countries (middle, bottom) ordered by the share of electric car sales in total car sales. Y-axes do not have the same scale to improve readability.
Source: IEA analysis based on country submissions, ACEA, EAFO, EV Volumes and Marklines.

Electric car sales exceeded 10 million in 2022, up 55% relative to 2021. Sales in China increased by 80% and accounted for 60% of global growth. Growth in Europe remained high (up 15%) and accelerated in the United States (up 55%).

Sales are expected to continue increasing in Europe, especially following recent policy developments under the 'Fit for 55' package. New rules set stricter CO_2 emission standards for 2030-2034 and target a 100% reduction in CO_2 emissions for new cars and vans from 2035 relative to 2021 levels. In the nearer term, an incentive mechanism operating between 2025 and 2029 will reward manufacturers that achieve a 25% car sales share of zero- and low-emission cars (17% for vans). In the first two months of 2023, battery electric car sales were already up by over 30% year-on-year, while overall car sales increased by just over 10% year-on-year.

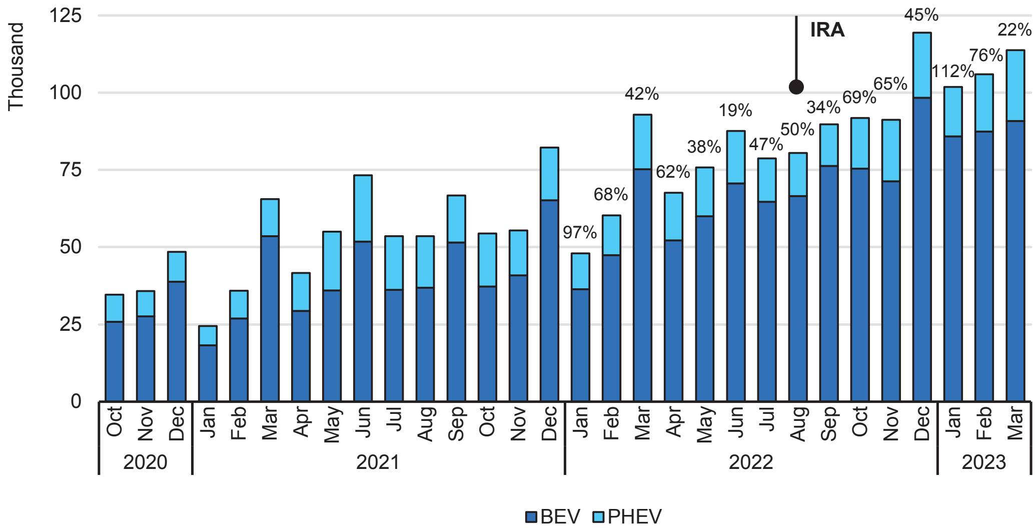
The United States confirms return to growth

In the United States, electric car sales increased 55% in 2022 relative to 2021, led by BEVs. Sales of BEVs increased by 70%, reaching nearly 800 000 and confirming a second consecutive year of strong growth after the 2019-2020 dip. Sales of PHEVs also grew, albeit by only 15%. The increase in electric car sales was particularly high in the United States, considering that total car sales dropped by 8% in 2022 relative to 2021, a much sharper decrease than the global average (minus 3%). Overall, the United States accounted for 10% of the global growth in sales. The total stock of electric cars reached 3 million, up 40% relative to 2021 and accounting for 10% of the global total. The share of electric cars in total car sales reached nearly 8%, up from just above 5% in 2021 and around 2% between 2018 and 2020.

A number of factors are helping to increase sales in the United States. A greater number of available models, beyond those offered by Tesla, the historic leader, helped to close the supply gap. Given that major companies like Tesla and General Motors had already reached their subsidy cap under US support in previous years,[5] new models from other companies being available means that more consumers can benefit from purchase incentives, which can be as high as USD 7 500. Awareness is increasing as government and companies lean towards electrification: in 2022, a quarter of Americans expect that their next car will be electric, according to the American Automobile Association. Although charging infrastructure and driving range have improved over the years, they remain major concerns for US drivers given the typically long travel distances and lower popularity and limited availability of alternatives such as rail. However, in 2021 the Bipartisan Infrastructure Law strengthened support for EV charging, allocating USD 5 billion in total funding over the 2022-2026 period through the National Electric Vehicle Infrastructure Formula Program, as well as USD 2.5 billion in competitive grants over the same period through the Charging and Fueling Infrastructure Discretionary Grant Program.

[5] Manufacturer caps were still in place for sales taking place in 2022, with models by carmakers having sold over 200 000 EVs losing eligibility for the purchase incentive, even if they were manufactured in North America following requirements under the IRA. Caps were removed starting from 2023.

Figure 1.4 Monthly new electric car registrations in the United States, 2020-2023



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; "IRA" refers to the Inflation Reduction Act. Percentage labels in 2022-2023 refer to year-on-year growth rates relative to the same month in the previous year.
Source: IEA analysis based on EV Volumes.

Monthly sales of electric cars have been steadily increasing in the United States, with further growth expected in 2023 as a result of strengthened policy support.

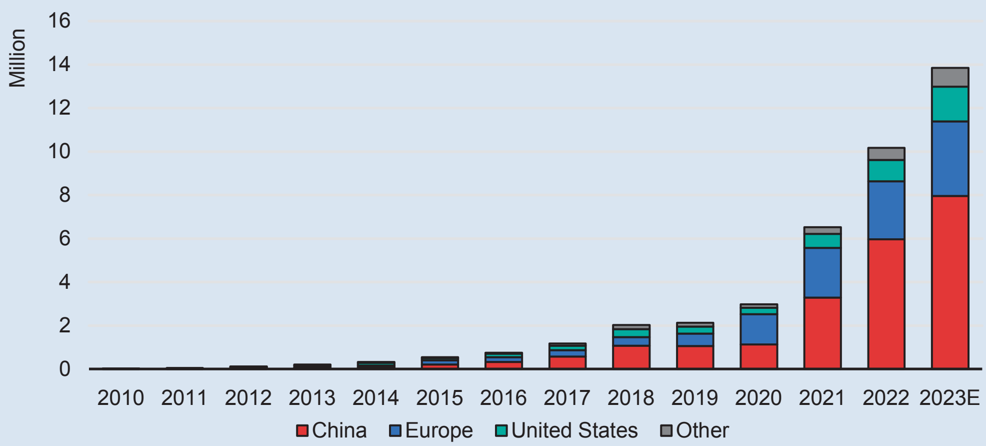
The acceleration in sales growth could continue in 2023 and beyond thanks to recent new policy support (see Prospects for electric vehicle deployment). The Inflation Reduction Act (IRA) has triggered a rush by global electromobility companies to expand US manufacturing operations. Between August 2022 and March 2023, major EV and battery makers announced cumulative post-IRA investments of USD 52 billion in North American EV supply chains, of which 50% is for battery manufacturing, and about 20% each for battery components and EV manufacturing. Overall, company announcements including tentative commitments for US investments for future battery and EV production add up to around USD 75-108 billion. As an example, Tesla plans to relocate its Berlin-based lithium-ion battery gigafactory to Texas, where it will work in partnership with China's CATL, and to manufacture next-generation EVs in Mexico. Ford also announced a deal with CATL for a battery plant in Michigan, and plans to increase electric car manufacturing sixfold by the end of 2023 relative to 2022, at 600 000 vehicles per year, scaling up to 2 million by 2026. BMW is seeking to expand EV manufacturing at its plant in South Carolina following the IRA. Volkswagen chose Canada for its first battery plant outside Europe, which will begin operations in 2027, and is also investing USD 2 billion in its plant in South Carolina. While these investments can be expected to lead to high growth in the years to come, the impact may only fully be seen from 2024 onwards as plants come online.

In the immediate term, the IRA has constrained eligibility requirements for purchase incentives, as vehicles need to be produced in North America in order to qualify for a subsidy. However, electric car sales have remained strong since August 2022 (Figure 1.4), and the first months of 2023 have been no exception: In the first quarter of 2023, electric car sales increased 60% compared to the same period in 2022, potentially boosted by the January 2023 removal of the subsidy caps for manufacturers, which means models by market leaders can now benefit from purchase incentives. In the longer-term, the list of models eligible for subsidies is expected to expand.

Box 1.1 The 2023 outlook for electric cars is bright

Early indications from first quarter sales of 2023 point to an upbeat market, supported by cost declines as well as strengthened policy support in key markets such as the United States. Globally, our current estimate is therefore for nearly 14 million electric cars to be sold in 2023, building on the more than 2.3 million already sold in the first quarter of the year. This represents a 35% increase in electric car sales in 2023 compared to 2022 and would bring the global electric sales share to around 18%, up from 14% in 2022.

Electric car sales, 2010-2023



Note: 2023 sales ("2023E") are estimated based on market trends through the first quarter of 2023.
Source: IEA analysis based on EV Volumes.

Electric car sales in the first three months of 2023 have shown strong signs of growth compared to the same period in 2022. In the United States, more than 320 000 electric cars were sold in the first quarter of 2023, 60% more than over the same period in 2022. Our current expectation is for this growth to be sustained throughout the year, with electric car sales reaching over 1.5 million in 2023, bringing the electric car sales share in the United States up to around 12% in 2023.

In China, electric car sales were off to a rough start in 2023, with January sales being 8% lower than in January 2022. The latest available data suggests a quick recovery: over the entire first quarter of 2023, electric car sales in China were more than 20% higher than in the first quarter of 2022, with more than 1.3 million electric cars being registered. For the remainder of 2023, we expect the generally favourable cost structure of electric cars to outweigh the effects of the phase-out of the NEV subsidy. As a result, our current expectation is for electric car sales in China to be more than 30% higher than in 2022 and reach around 8 million by the end of 2023, reaching a sales share of over 35% (from 29% in 2022).

Based on recent trends and tightening CO_2 targets not going into effect until 2025, the growth of electric car sales in Europe is expected to be the lowest of the three largest markets. In the first quarter of 2023, electric car sales in Europe increased by around 10% compared to the same period in 2022. For the full year, we currently expect electric car sales to increase by over 25%, with one-in-four cars sold in Europe being electric.

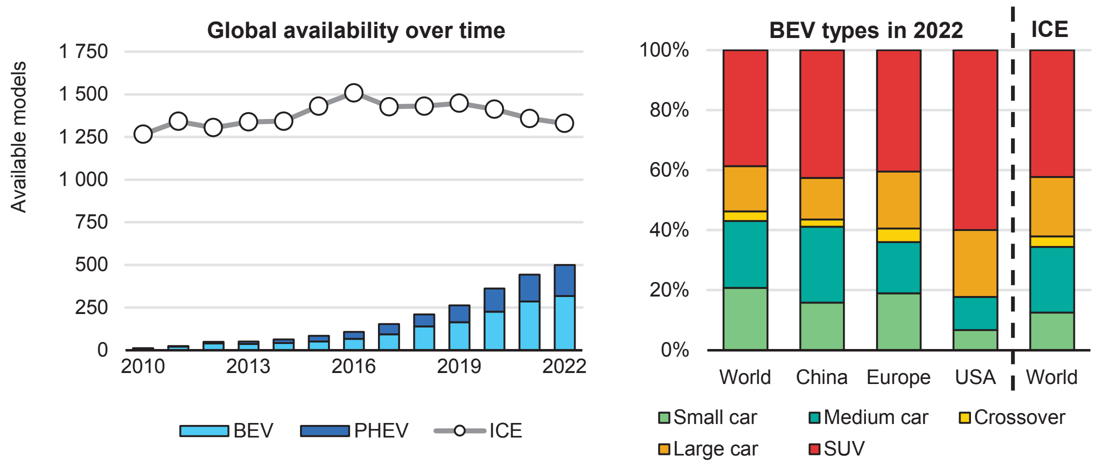
Outside of the major EV markets, electric car sales are expected to reach around 900 000 in 2023 – 50% higher than in 2022. Electric car sales in India in the first quarter of 2023 are already double what they were in the same period in 2022. In India and across all regions outside the three major EV markets, electric car sales are expected to represent 2-3% of car sales in 2023, a relatively small yet growing share.

There are, of course, downside risks to the 2023 outlook: a sluggish global economy and the phase-out of subsidies for NEVs in China could reduce 2023 growth in global electric car sales. On the upside, new markets may open up more quickly than anticipated, as persistent high oil prices make the case for EVs stronger in an increasing number of settings. And new policy developments, such as the April 2023 proposal from the US Environmental Protection Agency (EPA) to strengthen GHG emissions standards for cars, may send signals that boost sales even before going into effect.

The number of electric car models rises, especially for large cars and SUVs, at the same time as it decreases for conventional cars

The race to electrification is increasing the number of electric car models available on the market. In 2022, the number of available options reached 500, up from below 450 in 2021 and more than doubling relative to 2018-2019. As in previous years, China has the broadest portfolio with nearly 300 available models, double the number available in 2018-2019, prior to the Covid-19 pandemic. This remains nearly twice as many as in Norway, the Netherlands, Germany, Sweden, France and the United Kingdom, which all have around 150 models available, more than three times as many as before the pandemic. In the United States, there were fewer than 100 models available in 2022, but twice as many as before the pandemic; and 30 or fewer were available in Canada, Japan and Korea.

Figure 1.5 Car model availability by powertrain, 2010-2022 (left), and breakdown of available cars by powertrain and segment in 2022 (right)



IEA. CC BY 4.0.

Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle; ICE = internal combustion engine; SUV = sports utility vehicle; USA = United States. Analysis based on models for which there was at least one new registration in a given year; a model on sale but never sold is not counted, and as such actual model availability may be underestimated. In the chart on the right-hand side, distribution is based on the number of available models, not sales-weighted. Small cars include A and B segments. Medium cars include C and D segments. Crossovers are a type of sports utility vehicle (SUV) built on a passenger car platform. Large cars include E and F segments and multi-purpose vehicles.

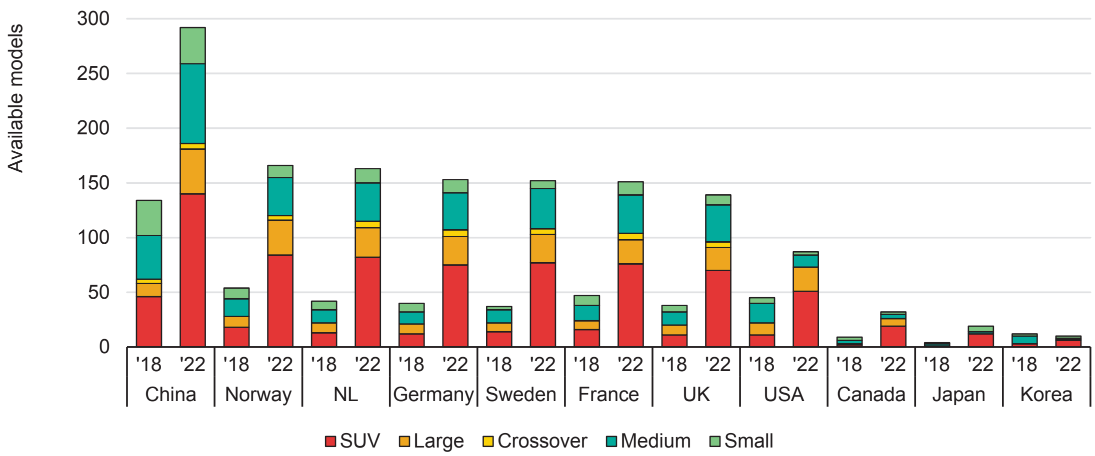
Source: IEA analysis based on Marklines.

The number of available electric car models reached 500 in 2022 but remains far below the number of ICE options. Large cars and SUVs still account for over half of available BEVs.

The 2022 trend reflects the increasing maturity of EV markets and demonstrates that carmakers are responding to increasing consumer demand for electric cars. However, the number of electric car models available remains much lower than that of conventional ICE cars, which has remained above 1 250 since 2010 and peaked at 1 500 in the middle of the past decade. In recent years, the number of ICE models sold has been steadily decreasing, at a compound annual growth rate of minus 2% over the 2016-2022 period, reaching about 1 300 models in 2022. This dip varies across major car markets and is most pronounced in China, where the number of available ICE options was 8% lower in 2022 than in 2016, versus 3-4% lower in the United States and Europe over the same period. This could result from contracting car markets and a progressive shift towards EVs among major carmakers. Looking forward, the total number of ICE models available could remain stable, while the number of new models shrinks, if carmakers focus on electrification and keep selling existing ICE options rather than increasing budgets to develop new models.

In contrast to ICE models, EV model availability has been growing quickly, at a compound annual growth rate of 30% over the 2016-2022 period. Such growth is to be expected in a nascent market with a large number of new entrants bringing innovative products to the market, and as incumbents diversify their portfolios. Growth has been slightly lower in recent years: the annual growth rate stood at around 25% in 2021 and 15% in 2022. In the future, the number of models can be expected to continue to increase quickly, as major carmakers expand their EV portfolios and new entrants strengthen their positions, particularly in emerging markets and developing economies (EMDEs). The historic number of ICE models available on the market suggests that the current number of EV options could double, at least, before stabilising.

Figure 1.6 Electric car model availability in selected countries by size, 2018-2022



Notes: NL = the Netherlands; UK = United Kingdom; USA = United States; SUV = sports utility vehicle. Includes battery electric vehicles and plug-in hybrid electric vehicles. Countries are ordered by the number of available models in 2022. Analysis based on models for which there was at least one new registration in a given year; a model on sale but never sold is not counted, and as such actual model availability may be underestimated.

Source: IEA analysis based on Marklines.

In 2022, 7 countries had around 150 EV models or more available for sale, up from 50 in 2018. The number of large models is increasing more quickly than that of small models.

SUVs and large car models dominate both EV and ICE markets

A major concern for global car markets – both EV and ICE – is the overwhelming dominance of SUVs and large models among available options. Carmakers are able to generate higher revenues from such models, given higher profit margins, which can cover some of the investments made in developing electric options. In certain cases, such as in the United States, larger vehicles can also benefit from less stringent fuel economy standards, hence creating an incentive for carmakers to slightly increase the vehicle size of a car for it to qualify as a light truck.

However, large models are more expensive, which poses significant affordability issues across the board, and all the more so in EMDEs. Large models also have implications for sustainability and supply chains, being equipped with larger batteries that require more critical minerals. In 2022, the sales-weighted average battery size of small battery electric cars ranged from 25 kWh in China to 35 kWh across France, Germany and the United Kingdom, and about 60 kWh in the United States. In comparison, the average for battery electric SUVs was around 70-75 kWh in these countries, and within the 75-90 kWh range for large car models.

Transitioning from ICE to electric is a priority for achieving net zero emissions targets, regardless of vehicle size, but mitigating the impacts of higher battery sizes will also be important. In France, Germany and the United Kingdom in 2022, the sales-weighted average weight of a battery electric SUV was 1.5 times higher than the average small battery electric car, requiring greater amounts of steel, aluminium and plastic; the battery in the SUV was twice as large, requiring about 75% more critical minerals. The CO_2 emissions associated with materials processing, manufacturing and assembly can be estimated at more than 70% higher as a result.

At the same time, in 2022, electric SUVs resulted in the displacement of over 150 000 barrels per day of oil consumption and avoided the associated tailpipe emissions that would have been generated through burning the fuel in combustion engines. Although electric SUVs represented roughly 35% of all electric passenger light-duty vehicles (PLDVs) in 2022, their share of oil displacement was even higher (about 40%), as SUVs tend to be driven more than smaller cars. Of course, smaller vehicles generally require less energy to operate and less materials to build, but electric SUVs certainly remain favourable to ICE vehicles.

In 2022, ICE SUVs emitted more than 1 Gt CO_2, far greater than the 80 Mt net emissions reductions from the electric vehicle fleet that year. While total car sales decreased by 0.5% in 2022, SUV sales increased by 3% relative to 2021, accounting for about 45% of total car sales, with noticeable growth in the United States, India and Europe. Of the 1 300 available options for ICE cars in 2022, more than 40% were SUVs, compared to fewer than 35% for small and medium cars. The total number of available ICE options went down from 2016 to 2022, but the drop was only for small and medium cars (down 35%) while large cars and SUVs increased (up 10%).

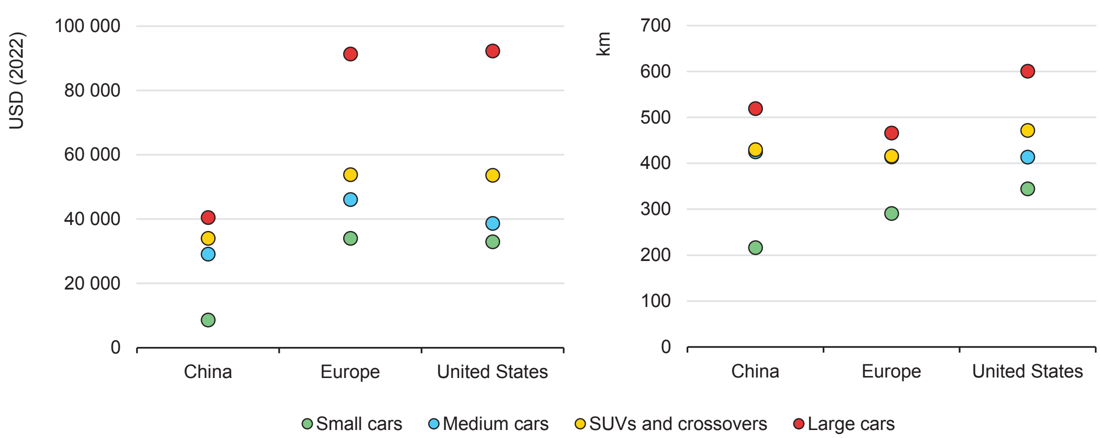
Similar trends are observed in EV markets. Around 16% of all SUVs sold were electric in 2022, which is above the overall market share of EVs and demonstrates consumer preferences for SUVs regardless of whether they are an ICE vehicle or EV. Nearly 40% of all BEV models available in 2022 were SUVs, which is equivalent to the shares of small and medium car options combined. Other large models accounted for more than 15%. Just 3 years before, in 2019, small and medium models accounted for 60% of all available models, and SUVs just 30%.

In China and Europe, SUVs and large models accounted for 60% of available BEV options in 2022, on par with the world average. As a comparison, ICE SUVs and large models accounted for about 70% of available ICE options in these regions, suggesting that electric cars currently remain somewhat smaller than their ICE equivalents. Announcements by some major European carmakers indicate that there could be a greater focus on smaller, more popular models in the years to come. For example, Volkswagen has announced the launch of a compact model for the European market under EUR 25 000 by 2025 and under EUR 20 000 by 2026-2027, as a means to appeal to a broader consumer base. In the United States, over 80% of available BEV options in 2022 were SUVs or large car models, which is greater than the share of ICE SUVs or large models at 70%. Looking ahead, more electric SUVs are to be expected in the United States, should recent policy announcements on expansion of IRA incentives to more SUVs be implemented. Following the IRA, the US Treasury has been revising vehicle classifications, and in 2023 changed the eligibility criteria for clean vehicle credits relevant to smaller SUVs, which are now eligible if priced under USD 80 000, up from the previous limit of USD 55 000.

Electric cars remain much cheaper in China

The growth in electric car sales in China has been underpinned by sustained policy support, but also cheaper retail prices. In 2022, the sales-weighted average price of a small BEV in China was below USD 10 000. This is significantly less than the prices of small BEVs found in Europe and the United States, where the sales-weighted average price exceeded USD 30 000 in the same year.

Figure 1.7 Sales-weighted average retail price (left) and driving range (right) of BEV passenger cars in selected countries, by size, in 2022



Notes: BEV = battery electric vehicle; SUV = sports utility vehicle. 'Europe' is based on data only from France, Germany and the United Kingdom. Retail prices collected in 2022-2023, before subsidy.
Source: IEA analysis based on EV Volumes.

In 2022, BEV passenger cars remained much cheaper in China, which explains in part higher adoption rates there.

In China, the best-selling electric cars in 2022 were the Wuling Mini BEV, a small model priced at under USD 6 500, and BYD's Dolphin, another small model, below USD 16 000. Together, these two models accounted for nearly 15% of Chinese BEV passenger car sales, illustrating the appetite for smaller models. To compare, the best-selling small BEVs across France, Germany and the United Kingdom – Fiat's 500, Peugeot's e-208 and Renault's Zoe – were all priced above USD 35 000. Few small BEVs were sold in the United States, limited mainly to Chevrolet's Bolt and the Mini Cooper BEV, which are priced around USD 30 000. Tesla's Y Model was the best-selling BEV passenger car in both the selected European countries (priced at more than USD 65 000) and the United States (more than USD 50 000).[6]

Chinese carmakers have focused on developing smaller and more affordable models in advance of their international peers, cutting down costs following years of tough competition domestically. Hundreds of small EV manufacturers have entered the market since the 2000s, benefitting from a variety of public support schemes, including subsidies and incentives for both consumers and manufacturers. The majority of these firms went bankrupt due to competition as subsidies were gradually phased out, and the market has since consolidated around a dozen frontrunners, which have succeeded in developing small and cheap electric cars for the Chinese market. Vertical integration of battery and EV supply chains from mineral processing to battery and EV manufacturing, as well as cheaper labour, manufacturing and access to finance across the board, have also contributed to developing cheaper models.

Meanwhile, carmakers in Europe and the United States – both early developers such as Tesla and incumbent major manufacturers – have mostly focused on larger or more luxurious models to date, hence offering few options affordable for mass-market consumers. However, the small options available in these countries typically offer greater performance than those in China, such as longer driving range. In 2022, the sales-weighted average range of small BEVs sold in the United States was nearly 350 km, while in France, Germany and the United Kingdom it was just under 300 km, compared to under 220 km in China. For other segments, the differences are less significant. The broader availability of public charging points in China may, in part, explain why consumers there have been more willing to opt for lower driving ranges than their European or American counterparts.

In 2022, Tesla heavily reduced the price of its models on two occasions as competition increased, and many carmakers have also announced cheaper options in the coming years. While these announcements warrant further examination, this trend could indicate that the price gap between small electric cars and incumbent ICE options could progressively close during this decade.

[6] However, Tesla has decreased car prices several times since the publication of the IRA in the United States, in part to boost sales as competition gets tougher (see section on corporate strategy and finance).

Actual vehicle range depends on the loaded vehicle weight, duty cycle, aerodynamics and drivetrain efficiency, as well as environmental factors such as temperature. In addition, as no harmonised test procedure currently exists to measure electric range for medium- and heavy-duty vehicles in any of the major markets where deployment of electric trucks has begun, manufacturers can determine their own methods to declare the electric range of the commercially available and announced models. However, any standardised test procedure would need to consider complicated issues of non-motive energy consumption (e.g. heating ventilation and air conditioning in buses, cooling in refrigerated trucks), as well as the potential for buses and trucks to be used in vehicle-to-grid applications (as has been demonstrated, for instance, with electric school buses in the United States). In light of such considerations, a first regulatory step could be to mandate that electric medium- and heavy-duty vehicle makers measure and disclose the usable battery energy according to a yet-to-be-developed standardised measurement procedure.

Charging infrastructure

Public charging points are increasingly necessary to enable wider EV uptake

While most of the charging demand is currently met by home charging, publicly accessible chargers are increasingly needed in order to provide the same level of convenience and accessibility as for refuelling conventional vehicles. In dense urban areas, in particular, where access to home charging is more limited, public charging infrastructure is a key enabler for EV adoption. At the end of 2022, there were 2.7 million public charging points worldwide, more than 900 000 of which were installed in 2022, about a 55% increase on 2021 stock, and comparable to the pre-pandemic growth rate of 50% between 2015 and 2019.

Slow chargers

Globally, more than 600 000 public slow charging points[11] were installed in 2022, 360 000 of which were in China, bringing the stock of slow chargers in the country to more than 1 million. At the end of 2022, China was home to more than half of the global stock of public slow chargers.

Europe ranks second, with 460 000 total slow chargers in 2022, a 50% increase from the previous year. The Netherlands leads in Europe with 117 000, followed by around 74 000 in France and 64 000 in Germany. The stock of slow chargers

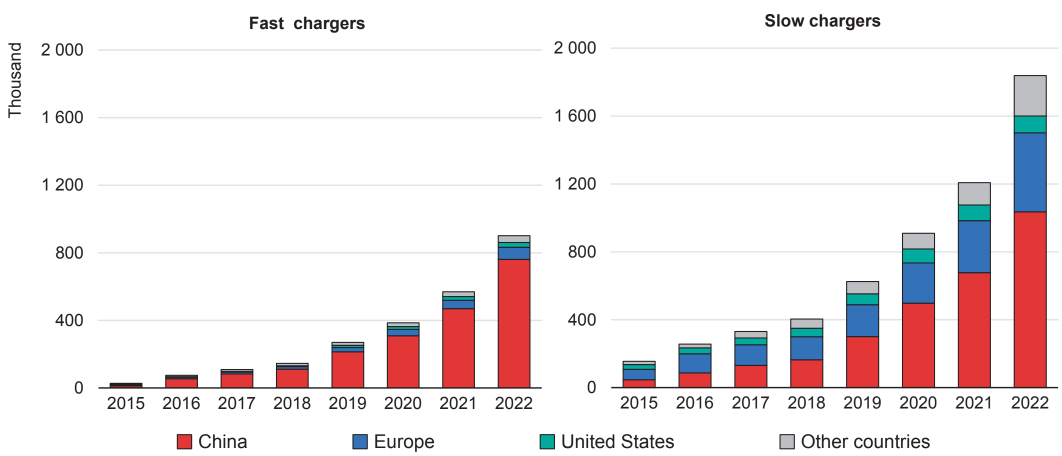
[11] Slow chargers have power ratings less than or equal to 22 kW. Fast chargers are those with a power rating of more than 22 kW and up to 350 kW. “Charging points” and “chargers” are used interchangeably and refer to the individual charging sockets, reflecting the number of EVs that can charge at the same time. ‘‘Charging stations” may have multiple charging points.

in the United States increased by 9% in 2022, the lowest growth rate among major markets. In Korea, slow charging stock has doubled year-on-year, reaching 184 000 charging points.

Fast chargers

Publicly accessible fast chargers, especially those located along motorways, enable longer journeys and can address range anxiety, a barrier to EV adoption. Like slow chargers, public fast chargers also provide charging solutions to consumers who do not have reliable access to private charging, thereby encouraging EV adoption across wider swaths of the population. The number of fast chargers increased by 330 000 globally in 2022, though again the majority (almost 90%) of the growth came from China. The deployment of fast charging compensates for the lack of access to home chargers in densely populated cities and supports China's goals for rapid EV deployment. China accounts for total of 760 000 fast chargers, but more than 70% of the total public fast charging pile stock is situated in just ten provinces.

Figure 1.13 Installed publicly accessible light-duty vehicle charging points by power rating and region, 2015-2022



Note: Values shown represent number of charging points.
Source: IEA analysis based on country submissions.

Installed publicly accessible charging points have increased by around 55%, with accelerated deployment led by China and Europe.

In Europe the overall fast charger stock numbered over 70 000 by the end of 2022, an increase of around 55% compared to 2021. The countries with the largest fast charger stock are Germany (over 12 000), France (9 700) and Norway (9 000). There is a clear ambition across the European Union to further develop the public charging infrastructure, as indicated by provisional agreement on the proposed

Alternative Fuels Infrastructure Regulation (AFIR), which will set electric charging coverage requirements across the trans-European network-transport (TEN-T).[12] An agreement between the European Investment Bank and the European Commission will make over EUR 1.5 billion available by the end of 2023 for alternative fuels infrastructure, including electric fast charging.

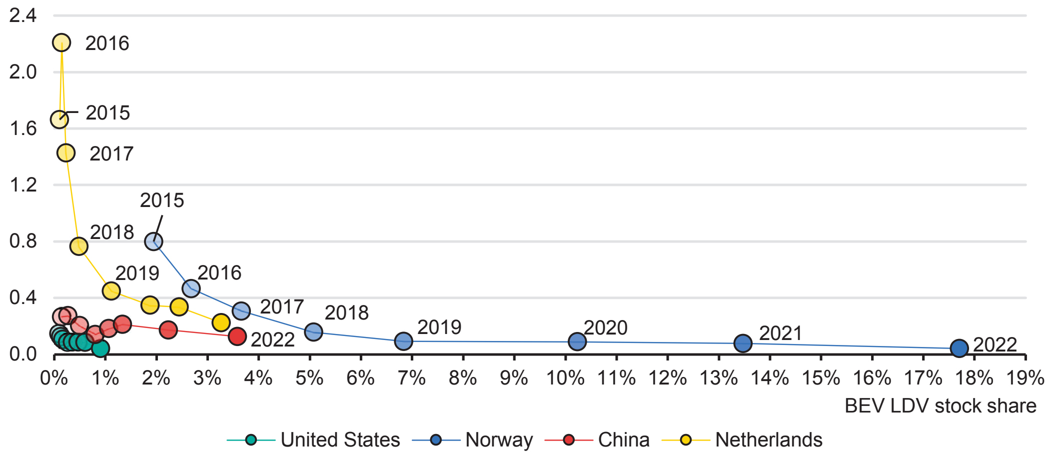
The United States installed 6 300 fast chargers in 2022, about three-quarters of which were Tesla Superchargers. The total stock of fast chargers reached 28 000 at the end of 2022. Deployment is expected to accelerate in the coming years following government approval of the National Electric Vehicle Infrastructure Formula Program (NEVI). All US states, Washington DC, and Puerto Rico are participating in the programme, and have already been allocated USD 885 million in funding for 2023 to support the build-out of chargers across 122 000 km of highway (see Policy support for EV charging infrastructure). The US Federal Highway Administration has announced new national standards for federally funded EV chargers to ensure consistency, reliability, accessibility and compatibility. As a result of the new standards, Tesla has announced it will open a portion of its US Supercharger (where Superchargers represent 60% of the total stock of fast chargers in the United States) and Destination Charger network to non-Tesla EVs.

Ratio of electric LDVs per public charger

Deployment of public charging infrastructure in anticipation of growth in EV sales is critical for widespread EV adoption. In Norway, for example, there were around 1.3 battery electric LDVs per public charging point in 2011, which supported further adoption. At the end of 2022, with over 17% of LDVs being BEVs, there were 25 BEVs per public charging point in Norway. In general, as the stock share of battery electric LDVs increases, the charging point per BEV ratio decreases. Growth in EV sales can only be sustained if charging demand is met by accessible and affordable infrastructure, either through private charging in homes or at work, or publicly accessible charging stations.

[12] Previously a directive, the proposed AFIR, once formally approved, would become a binding legislative act, stipulating, among other things, a maximum distance between chargers installed along the TEN-T, the primary and secondary roads within the European Union.

Figure 1.14 Public charging points per battery electric light-duty vehicle ratio in selected countries against battery electric light-duty vehicle stock share, 2015-2022



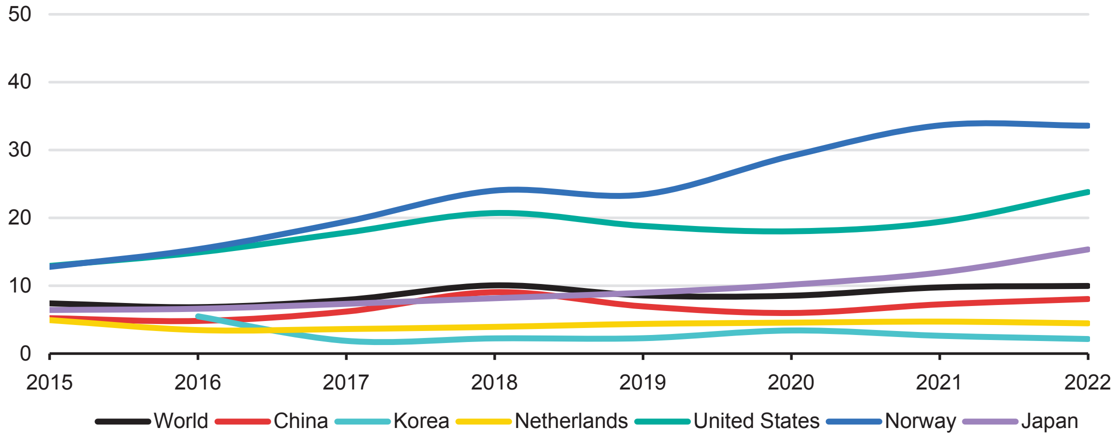
Notes: BEV = battery electric vehicle; LDV = light-duty vehicle. Charging points include only publicly available chargers, both fast and slow. Shading grows darker each year.
Source: IEA analysis based on country submissions.

In many advanced markets, as the stock share of battery electric LDVs increased, the charging point per BEV ratio has decreased.

While PHEVs are less reliant on public charging infrastructure than BEVs, policy-making relating to the sufficient availability of charging points should incorporate (and encourage) public PHEV charging. If the total number of electric LDVs per charging point is considered, the global average in 2022 was about ten EVs per charger. Countries such as China, Korea and the Netherlands have maintained fewer than ten EVs per charger throughout past years. In countries that rely heavily on public charging, the number of publicly accessible chargers has been expanding at a speed that largely matches EV deployment.

However, in some markets characterised by widespread availability of home charging (due to a high share of single-family homes with the opportunity to install a charger) the number of EVs per public charging point can be even higher. For example, in the United States, the ratio of EVs per charger is 24, and in Norway is more than 30. As the market penetration of EVs increases, public charging becomes increasingly important, even in these countries, to support EV adoption among drivers who do not have access to private home or workplace charging options. However, the optimal ratio of EVs per charger will differ based on local conditions and driver needs.

Figure 1.15 Electric light-duty vehicle per public charging point, 2010-2022



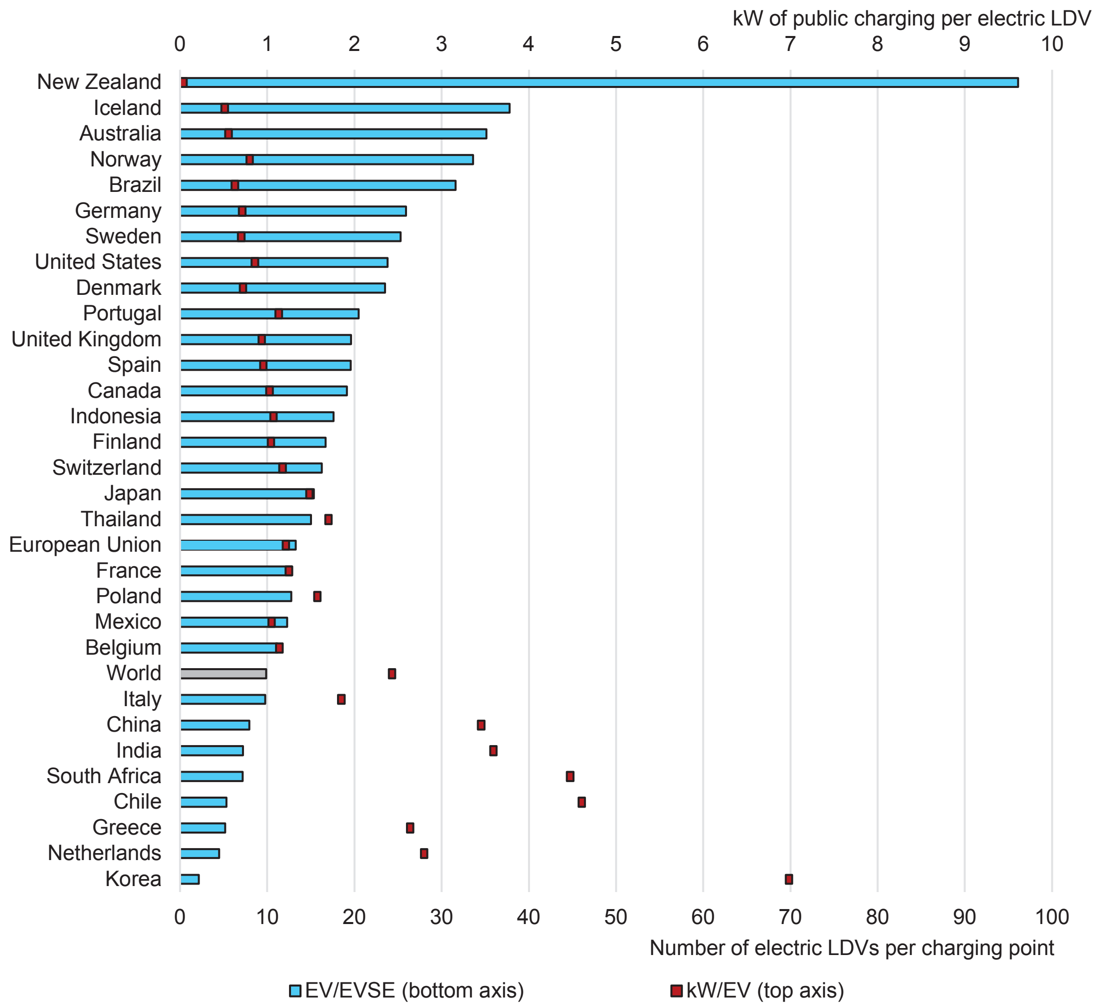
Note: Charging points include only publicly available chargers, both fast and slow.
Source: IEA analysis based on country submissions.

Countries show different speeds in public charging deployment as the number of EVs on the road increases.

Perhaps more important than the number of public chargers available is the total public charging power capacity per EV, given that fast chargers can serve more EVs than slow chargers. During the early stages of EV adoption, it makes sense for available charging power per EV to be high, assuming that charger utilisation will be relatively low until the market matures and the utilisation of infrastructure becomes more efficient. In line with this, the European Union's provisional agreement on the AFIR includes requirements for the total power capacity to be provided based on the size of the registered fleet.

Globally, the average public charging power capacity per electric LDV is around 2.4 kW per EV. In the European Union, the ratio is lower, with an average around 1.2 kW per EV. Korea has the highest ratio at 7 kW per EV, even with most public chargers (90%) being slow chargers.

Figure 1.16 Number of electric light-duty vehicles per public charging point and kW per electric light-duty vehicle, 2022



Notes: EV = electric vehicle; EVSE = electric vehicle supply equipment; LDV = light-duty vehicle. Kilowatts per EV are estimated assuming 11 kW for slow and 50 kW for fast chargers. Official national metrics might differ from these values as they can rely on more granular data.

Source: IEA analysis based on country submissions.

The number of electric light-duty vehicles per public EV charging point varies dramatically between countries, ranging from about 2 vehicles per charging point in Korea to almost 100 in New Zealand.

Charging needs for heavy-duty vehicles

In the regions where electric trucks are becoming commercially available, battery electric trucks can compete on a TCO basis with conventional diesel trucks for a growing range of operations, not only urban and regional, but also in the heavy-duty tractor-trailer regional and long-haul segments. Three parameters that determine the time at which TCO parity is reached are tolls; fuel and operations costs (e.g. the difference between diesel and electricity prices faced by truck operators, and reduced maintenance costs); and CAPEX subsidies to reduce the gap in the upfront vehicle purchase price. Since electric trucks can provide the same operations with lower lifetime costs (including if a discounted rate is applied), the time horizon in which vehicle owners expect to recuperate upfront costs is a key factor in determining whether to purchase an electric or conventional truck.

The economics for electric trucks in long-distance applications can be substantially improved if charging costs can be reduced by maximising “off-shift” (e.g. night-time or other longer periods of downtime) slow charging, securing bulk purchase contracts with grid operators for “mid-shift” (e.g. during breaks), fast (up to 350 kW), or ultra-fast (>350 kW) charging, and exploring smart charging and vehicle-to-grid opportunities for extra income.

Electric trucks and buses will rely on off-shift charging for the majority of their energy. This will be largely achieved at private or semi-private charging depots or at public stations on highways, and often overnight. Depots to service growing demand for heavy-duty electrification will need to be developed, and in many cases may require distribution and transmission grid upgrades. Depending on vehicle range requirements, depot charging will be sufficient to cover most operations in urban bus as well as urban and regional truck operations.

The major constraint to rapid commercial adoption of electric trucks in regional and long-haul operations is the availability of “mid-shift” fast charging. Although the majority of energy requirements for these operations could come from “off-shift” charging, fast and ultra-fast charging will be needed to extend range such that operations currently covered by diesel can be performed by battery electric trucks with little to no additional dwell time (i.e. waiting). Regulations that mandate rest periods can also provide a time window for mid-shift charging if fast or ultra-fast charging options are available en route: the European Union requires 45 minutes of break after every 4.5 hours of driving; the United States mandates 30 minutes after 8 hours.

Most commercially available direct current (DC) fast charging stations currently enable power levels ranging from 250-350 kW. The European Union’s Alternative Fuels Infrastructure Regulation (AFIR) aims to enable mid-shift charging across the EU’s core TEN-T network, which covers 88% of total long-haul freight activity, and along other key freight corridors. The provisional agreement reached by the European Council and Parliament includes a gradual process of infrastructure deployment for electric heavy-duty vehicles starting in 2025. Recent studies of power requirements for regional and long-haul truck operations in the United States and Europe find that charging power higher than 350 kW, and as high as 1 MW, may be required to fully recharge electric trucks during a 30- to 45-minute break.

Recognising the need to scale up fast or ultra-fast charging as a prerequisite for making both regional and, in particular, long-haul operations technically and economically viable, in 2022 Traton, Volvo, and Daimler established an independent joint venture, Milence. With EUR 500 million in collective investments from the three heavy-duty manufacturing groups, the initiative aims to deploy more than 1 700 fast (300 to 350 kW) and ultra-fast (1 MW) charging points across Europe.

Multiple charging standards are currently in use, and technical specifications for ultra-fast charging are under development. Ensuring maximum possible convergence of charging standards and interoperability for heavy-duty EVs will be needed to avoid the cost, inefficiency, and challenges for vehicle importers and international operators that would be created by manufacturers following divergent paths.

In China, co-developers China Electricity Council and CHAdeMO's "ultra ChaoJi" are developing a charging standard for heavy-duty electric vehicles for up to several megawatts. In Europe and the United States, specifications for the CharIN Megawatt Charging System (MCS), with a potential maximum power of 4.5 MW, are under development by the International Organization for Standardization (ISO) and other organisations. The final MCS specifications, which will be needed for commercial roll-out, are expected for 2024. After the first megawatt charging site offered by Daimler Trucks and Portland General Electric (PGE) in 2021, at least twelve high-power charging projects are planned or underway in the United States and Europe, including charging of an electric Scania truck in Oslo, Norway, at a speed of over 1 MW, Germany's HoLa project, and the Netherlands Living Lab Heavy-Duty and Green Transport Delta Charging Stations, as well as investments and projects in Austria, Sweden, Spain and the United Kingdom.

Commercialisation of chargers with rated power of 1 MW will require significant investment, as stations with such high-power needs will incur significant costs in both installation and grid upgrades. Revising public electric utility business models and power sector regulations, co-ordinating planning across stakeholders and smart charging can all help to manage grid impacts. Direct support through pilot projects and financial incentives can also accelerate demonstration and adoption in the early stages. A recent study outlines some key design considerations for developing MCS rated charging stations:

- Planning charging stations at highway depot locations near transmission lines and substations can be an optimal solution for minimising costs and increasing charger utilisation.
- "Right-sizing" connections with direct connections to transmission lines at an early stage, thereby anticipating the energy needs of a system in which high shares of freight activity have been electrified, rather than upgrading distribution grids on an

ad-hoc and short-term basis, will be critical to reduce costs. This will require structured and co-ordinated planning between grid operators and charging infrastructure developers across sectors.

- Since transmission system interconnections and grid upgrades can take 4-8 years, siting and construction of high-priority charging stations will need to begin as soon as possible.

Alternative solutions include installing stationary storage and integrating local renewable capacity, combined with smart charging, which can help reduce both infrastructure costs related to grid connection and electricity procurement costs (e.g. by enabling truck operators to minimise cost by arbitraging price variability throughout the day, taking advantage of vehicle-to-grid opportunities, etc.).

Other options to provide power to electric heavy-duty vehicles (HDVs) are battery swapping and electric road systems. Electric road systems can transfer power to a truck either via inductive coils[13] in a road, or through conductive connections between the vehicle and road, or via catenary (overhead) lines. Catenary and other dynamic charging options may hold promise for reducing the uncertainty of system-level costs in the transition to zero-emission regional and long-haul trucks, competing favourably in terms of total capital and operating costs. They can also help to reduce battery capacity needs. Battery demand can be further reduced, and utilisation further improved, if electric road systems are designed to be compatible not only with trucks but also electric cars. However, such approaches would require inductive or in-road designs that come with greater hurdles in terms of technology development and design, and are more capital intensive. At the same time, electric road systems pose significant challenges resembling those of the rail sector, including a greater need for standardisation of paths and vehicles (as illustrated with trams and trolley buses), compatibility across borders for long-haul trips, and appropriate infrastructure ownership models. They provide less flexibility for truck owners in terms of routes and vehicle types, and have high development costs overall, all affecting their competitiveness relative to regular charging stations. Given these challenges, such systems would most effectively be deployed first on heavily used freight corridors, which would entail close co-ordination across various public and private stakeholders. Demonstrations on public roads to date in Germany and Sweden have relied on champions from both private and public entities. Calls for electric road system pilots are also being considered in the China, India, the United Kingdom and the United States.

[13] Inductive solutions are further from commercialisation and face challenges to deliver sufficient power at highway speeds.

in 2022, and the company has set a target of 4 000 battery swap stations globally by 2025. The company claims their swap stations can perform over 300 swaps per day, charging up to 13 batteries concurrently at a power of 20-80 kW.

NIO also announced plans to build battery swap stations in Europe as their battery swapping-enabled car models became available in European markets towards the end of 2022. The first NIO battery swap station in Sweden was opened in November 2022, and by the end of 2022, ten NIO battery swap stations had been opened across Norway, Germany, Sweden and the Netherlands. In contrast to NIO, whose swapping stations service NIO cars, the Chinese battery swapping station operator Aulton's stations support 30 models from 16 different vehicle companies.

Battery swapping could also be a particularly attractive option for LDV taxi fleets, whose operations are more sensitive to recharging times than personal cars. US start-up Ample currently operates 12 battery swapping stations in the San Francisco Bay area, mainly serving Uber rideshare vehicles.

Batteries

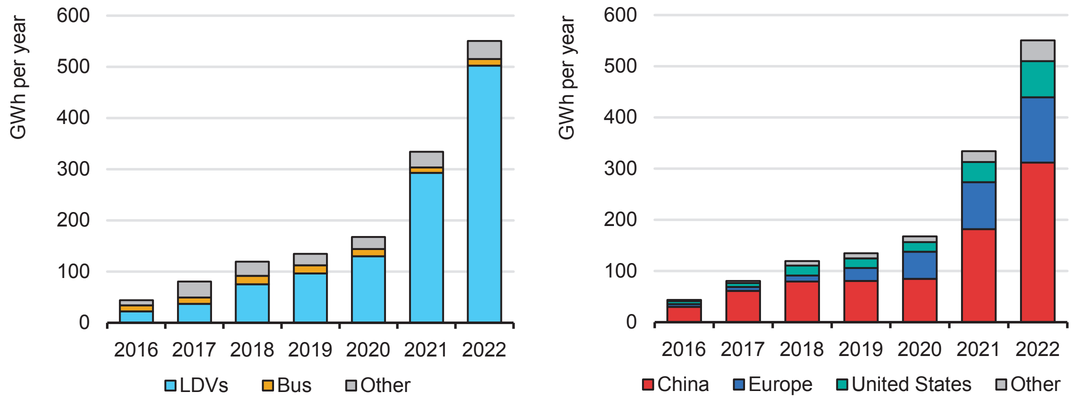
Battery demand for EVs continues to rise

Automotive lithium-ion (Li-ion) battery demand increased by about 65% to 550 GWh in 2022, from about 330 GWh in 2021, primarily as a result of growth in electric passenger car sales, with new registrations increasing by 55% in 2022 relative to 2021.

In China, battery demand for vehicles grew over 70%, while electric car sales increased by 80% in 2022 relative to 2021, with growth in battery demand slightly tempered by an increasing share of PHEVs. Battery demand for vehicles in the United States grew by around 80%, despite electric car sales only increasing by around 55% in 2022. While the average battery size for battery electric cars in the United States only grew by about 7% in 2022, the average battery electric car battery size remains about 40% higher than the global average, due in part to the higher share of SUVs in US electric car sales relative to other major markets,[14] as well as manufacturers' strategies to offer longer all-electric driving ranges. Global sales of BEV and PHEV cars are outpacing sales of hybrid electric vehicles (HEVs), and as BEV and PHEV battery sizes are larger, battery demand further increases as a result.

[14] For more information on the climate impact of SUVs, refer to the IEA's 27 February 2023 commentary on the subject.

Figure 1.17 Battery demand by mode and region, 2016-2022



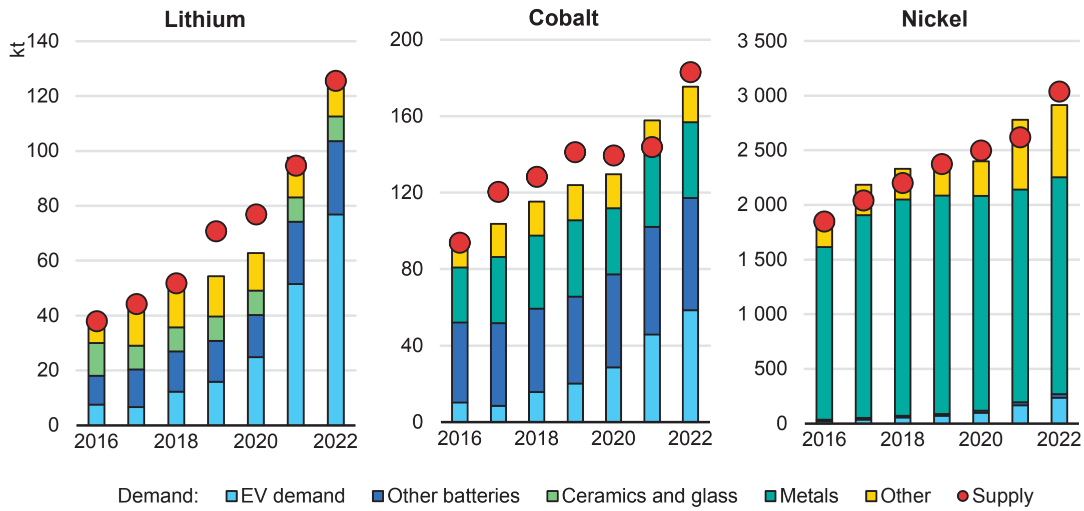
Notes: LDVs = light-duty vehicles, including cars and vans; In the left chart, “Other” includes medium- and heavy-duty trucks and two/three-wheelers. Battery demand refers to automotive lithium-ion batteries. This analysis does not include conventional hybrid vehicles.
Source: IEA analysis based on EV Volumes.

Global battery demand increased by 65% in 2022, mainly as a result of electric car sales in China.

The increase in battery demand drives the demand for critical materials. In 2022, lithium demand exceeded supply (as in 2021) despite the 180% increase in production since 2017. In 2022, about 60% of lithium, 30% of cobalt and 10% of nickel demand was for EV batteries. Just five years earlier, in 2017, these shares were around 15%, 10% and 2%, respectively. As has already been seen for lithium, mining and processing of these critical minerals will need to increase rapidly to support the energy transition, not only for EVs but more broadly to keep up with the pace of demand for clean energy technologies.[15] Reducing the need for critical materials will also be important for supply chain sustainability, resilience and security. Accelerating innovation can help, such as through advanced battery technologies requiring smaller quantities of critical minerals, as well as measures to support uptake of vehicle models with optimised battery size and the development of battery recycling.

[15] For more information on the future of supply and demand of critical minerals, refer to the Energy Technology Perspective 2023 report.

Figure 1.18 Overall supply and demand of battery metals by sector, 2016-2022



Note: EV = electric vehicle. The metals category includes alloying applications. Supply refers to refinery output and not mining output.

Source: IEA analysis based on Mineral Commodity Summary 2022 by USGS, lithium and cobalt global supply-demand balance (January 2023) and nickel global supply-demand balance (January 2023) from S&P Global and World Metal Statistics Yearbook by the World Bureau of Metal Statistics.

In 2022, supply of nickel and cobalt exceeded demand, while lithium demand outpaced supply by a small margin.

Battery chemistries are diversifying

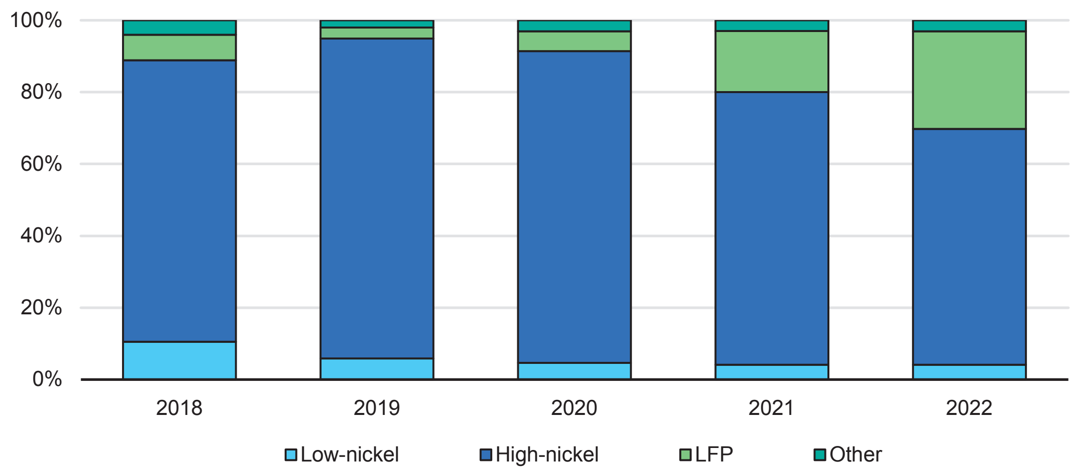
New alternatives to conventional lithium-ion are on the rise

In 2022, lithium nickel manganese cobalt oxide (NMC) remained the dominant battery chemistry with a market share of 60%, followed by lithium iron phosphate (LFP) with a share of just under 30%, and nickel cobalt aluminium oxide (NCA) with a share of about 8%.

Lithium iron phosphate (LFP) cathode chemistries have reached their highest share in the past decade (Figure 1.19). This trend is driven mainly by the preferences of Chinese OEMs. Around 95% of the LFP batteries for electric LDVs went into vehicles produced in China, and BYD alone represents 50% of demand. Tesla accounted for 15%, and the share of LFP batteries used by Tesla increased from 20% in 2021 to 30% in 2022. Around 85% of the cars with LFP batteries manufactured by Tesla were manufactured in China, with the remainder being manufactured in the United States with cells imported from China. In total, only around 3% of electric cars with LFP batteries were manufactured in the United States in 2022.

LFP batteries contrast with other chemistries in their use of iron and phosphorus rather than the nickel, manganese and cobalt found in NCA and NMC batteries. The downside of LFP is that the energy density tends to be lower than that of NMC. LFP batteries also contain phosphorus, which is used in food production. If all batteries today were LFP, they would account for nearly 1% of current agricultural phosphorus use by mass, suggesting that conflicting demands for phosphorus may arise in the future as battery demand increases.

Figure 1.19 Electric light-duty vehicle battery capacity by chemistry, 2018-2022

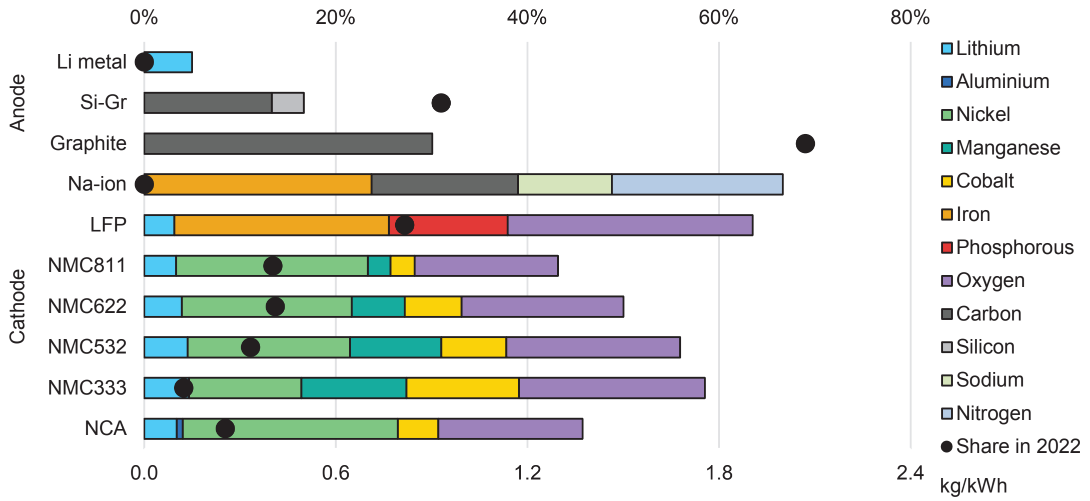


Notes: LFP = Lithium iron phosphate. Low-nickel includes: NMC333. High-nickel includes: NMC532, NMC622, NMC721, NMC811, NCA and NMCA. Cathode sales share is based on battery capacity.
Source: IEA analysis based on EV Volumes.

The share of lithium iron phosphate reached its highest ever point, accounting for almost 30% of new electric LDV battery capacity in 2022.

With regards to anodes, a number of chemistry changes have the potential to improve energy density (watt-hour per kilogram, or Wh/kg). For example, silicon can be used to replace all or some of the graphite in the anode in order to make it lighter and thus increase the energy density. Silicon-doped graphite already entered the market a few years ago, and now around 30% of anodes contain silicon. Another option is innovative lithium metal anodes, which could yield even greater energy density when they become commercially available (Figure 1.20).

Figure 1.20 Material content in different anode and cathodes



Notes: Li metal = Lithium metal anode; Si-Gr = Silicon-graphite anode; Graphite = Pure graphite anode; Na-ion = Sodium-ion; LFP = Lithium iron phosphate; NMC = Lithium nickel manganese cobalt oxide; NCA = Lithium nickel cobalt aluminium oxide. Materials composing the battery casing and the electrolyte are excluded. Chemistry shares are based on demand. The share of NCA battery includes every NCA type and Si-Gr includes every degree of silicon-graphite mix. Carbon covers the graphite composing anodes. The Na-ion cathode shown is the Prussian white.

Source: IEA analysis based on Lithium-Ion Batteries: State of the Industry 2022 by BNEF, BatPaC v4 by Argonne Laboratory and Sodium-ion batteries: disrupt and conquer? by Wood Mackenzie.

Lithium iron phosphate cathodes do not rely on nickel, manganese or cobalt, which has contributed to their increased market share.

In recent years, alternatives to Li-ion batteries have been emerging, notably sodium-ion (Na-ion). This battery chemistry has the dual advantage of relying on lower cost materials than Li-ion, leading to cheaper batteries, and of completely avoiding the need for critical minerals. It is currently the only viable chemistry that does not contain lithium. The Na-ion battery developed by China's CATL is estimated to cost 30% less than an LFP battery. Conversely, Na-ion batteries do not have the same energy density as their Li-ion counterpart (respectively 75 to 160 Wh/kg compared to 120 to 260 Wh/kg). This could make Na-ion relevant for urban vehicles with lower range, or for stationary storage, but could be more challenging to deploy in locations where consumers prioritise maximum range autonomy, or where charging is less accessible. There are nearly 30 Na-ion battery manufacturing plants currently operating, planned or under construction, for a combined capacity of over 100 GWh, almost all in China. For comparison, the current manufacturing capacity of Li-ion batteries is around 1 500 GWh.

Multiple carmakers have already announced Na-ion electric cars, such as the Seagull by BYD, which has an announced range of 300 km and is sold for USD 11 600 (with possible discounts bringing the price down to USD 9 500), and the Sehol EX10, produced by the VW-JAC joint venture, with a 250 km range.

While these first models are likely to be slightly more expensive than the cheapest small BEV models in China – such as the Wuling Mini BEV, sold for as little as USD 5 000 to 6 500 – they are still cheaper than equivalent options with similar driving range. To compare, the Wuling Mini BEV's range stands at 170 km, but BYD's Dolphin BEV, the second best-selling small BEV in China in 2022, with a similar range to the announced Na-ion cars, can cost more than USD 15 000. BYD plans to progressively integrate Na-ion batteries into all its models below USD 29 000 as battery production ramps up. These announcements suggest that electric vehicles powered by Na-ion will be available for sale and driven for the first time in 2023-2024, hence bringing the technology to a readiness level (TRL[16]) of 8-9, between first-of-a-kind commercial and commercial operation in the relevant environment. In 2022, it was assessed at TRL 6 (full prototype at scale) in the IEA Clean Technology Guide, compared to only TRL 3-4 (small prototypes) in the assessment from 2021, highlighting quick technological progress.

Critical mineral prices can have an impact on chemistry choice

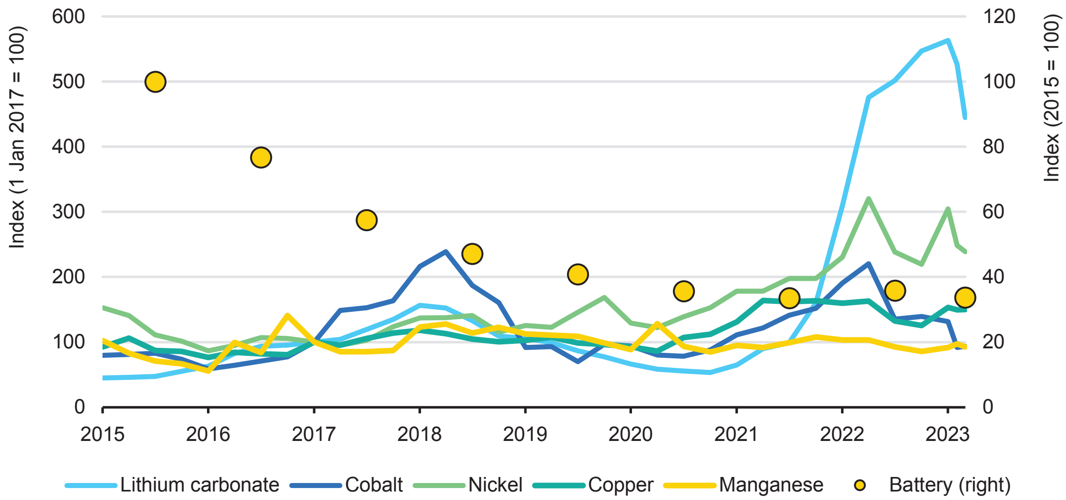
The variability in price and availability of critical minerals can also explain some of the developments in battery chemistry from the last few years (Figure 1.21). NMC chemistries using an equal ratio of nickel, manganese, and cobalt (NMC333 or NMC111) were popular until 2015. Since then, cobalt price increases and concerns affecting public acceptance of cobalt mining have contributed to a shift towards lower-cobalt ratios, such as NMC622, and then NMC811, which are nevertheless more difficult to manufacture. In 2022, the price of nickel increased, reaching a peak twice as high as the 2015-2020 average. This created incentives to use chemistries that are less reliant on nickel, such as LFP, despite their lower energy density.

Lithium carbonate prices have also been steadily increasing over the past two years. In 2021, prices multiplied four- to five-fold, and continued to rise throughout 2022, nearly doubling between 1 January 2022 and 1 January 2023. At the beginning of 2023, lithium prices stood six times above their average over the 2015-2020 period. In contrast to nickel and lithium, manganese prices have been relatively stable. One reason for the increase in prices for lithium, nickel and cobalt was the insufficient supply compared to demand in 2021 (Figure 1.18). Although nickel and cobalt supply surpassed demand in 2022, this was not the case for lithium, causing its price to rise more strongly over the year. Between January and March 2023, lithium prices dropped 20%, returning to their late 2022 level. The combination of an expected 40% increase in supply and slower growth in demand, especially for EVs in China, has contributed to this trend. This drop – if sustained – could translate into lower battery prices.

[16] Technology Readiness Level (TRL) provides a snapshot of the maturity of a given technology. It has 11 steps ranging from initial idea at step 1 to proof of stability reached at step 11. For more information, refer to the IEA Clean Technology Guide.

Beyond those materials, global commodity prices have surged in the last few years, as a result of supply disruptions in the wake of the Covid-19 pandemic, rising demand as the global economy started to recover, and Russia's invasion of Ukraine in February 2022, among other factors.

Figure 1.21 Price of selected battery materials and lithium-ion batteries, 2015-2023



Notes: Data until March 2023. Lithium-ion battery prices (including the pack and cell) represent the global volume-weighted average across all sectors. Nickel prices are based on the London Metal Exchange, used here as a proxy for global pricing, although most nickel trade takes place through direct contracts between producers and consumers. The 2023 battery price value is based on cost estimates for NMC 622.

Source: IEA analysis based on material price data by S&P, 2022 Lithium-Ion Battery Price Survey by BNEF and Battery Costs Drop as Lithium Prices in China Fall by BNEF.

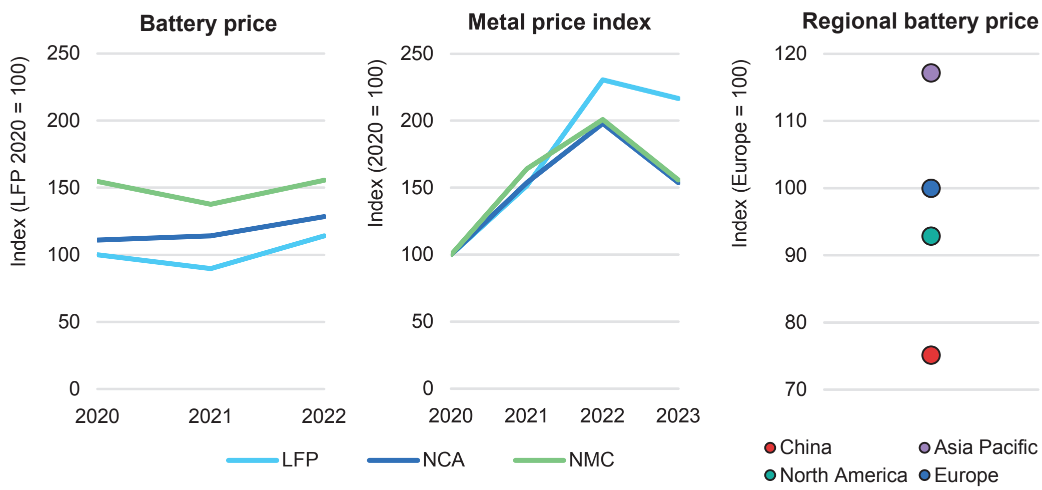
From 2021 to the end of 2022, the price of critical materials such as lithium, cobalt and nickel increased dramatically, putting pressure on historical Li-ion battery price decreases.

In 2022, the estimated average battery price stood at about USD 150 per kWh, with the cost of pack manufacturing accounting for about 20% of total battery cost, compared to more than 30% a decade earlier. Pack production costs have continued to decrease over time, down 5% in 2022 compared to the previous year. In contrast, cell production costs increased in 2022 relative to 2021, returning to 2019 levels. This can be explained in part by the increasing prices of materials, which account for a significant portion of cell price, and of electricity, which affects manufacturing costs, whereas efficiency gains in pack manufacturing help decrease costs. Bloomberg New Energy Finance (BNEF) sees pack manufacturing costs dropping further, by about 20% by 2025, whereas cell production costs decrease by only 10% relative to their historic low in 2021. This warrants further analysis based on future trends in material prices.

The effect of increased battery material prices differed across various battery chemistries in 2022, with the strongest increase being observed for LFP batteries (over 25%), while NMC batteries experienced an increase of less than 15% (Figure 1.21). Since LFP batteries contain neither nickel nor cobalt, which are relatively expensive compared to iron and phosphorus, the price of lithium plays a relatively larger role in determining the final cost. Given that the price of lithium increased at a higher rate than the price of nickel and cobalt, the price of LFP batteries increased more than the price of NMC batteries. Nonetheless, LFP batteries remain less expensive than NCA and NMC per unit of energy capacity.

The price of batteries also varies across different regions, with China having the lowest prices on average, and the rest of the Asia Pacific region having the highest (Figure 1.21). This price discrepancy is influenced by the fact that around 65% of battery cells and almost 80% of cathodes are manufactured in China.

Figure 1.22 Price index for selected battery chemistries, regions and metal price, 2020-2023



Note: LFP = Lithium iron phosphate; NMC = Lithium nickel manganese cobalt oxide; NCA = Lithium nickel cobalt aluminium oxide. The metal price index is based on the price evolution of four commodities (lithium carbonate, cobalt, nickel and copper) weighted by their use in each battery chemistry. For this metal price index, NMC uses the NMC622 chemistry. The 2023 value of the metal price index covers only the first 3 months of the year. Asia Pacific excludes China. Regional battery (pack) price refers to 2022.

Source: IEA analysis based on material price data by S&P, 2022 Lithium-Ion Battery Price Survey by BNEF, BatPaC v4 by Argonne Laboratory and Lithium-Ion Batteries: State of the Industry 2022 by BNEF.

Despite a higher relative increase in price compared to other battery chemistries, LFP batteries remain the lowest price per kWh.

Prospects for electric vehicle deployment

Several pathways to electrify road transport in the period to 2030 are explored in this section. First, deployment of electric vehicles (EVs) is projected by region and road segment for the Stated Policies and Announced Pledges scenarios, and globally by segment for the Net Zero Emissions by 2050 Scenario. These projections are then compared to announcements by original equipment manufacturers (OEMs). Then the corresponding battery demand is projected, followed by roll-out requirements for charging infrastructure. Finally, the impacts of EV deployment are assessed, including increased electricity demand, oil displacement, implications for tax revenues, and net well-to-wheels GHG emissions.

Outlook for electric mobility

Scenarios

A scenario-based approach is used to explore road transport electrification and its impact, based on the latest market data, policy drivers and technology perspectives. Two IEA scenarios – the Stated Policies and Announced Pledges scenarios – inform the outlooks, which are examined in relation to the Net Zero Emissions by 2050 Scenario at the global level.[1] These scenarios are based on announced policies, ambitions and market trends through the first quarter of 2023.

The purpose of the scenarios is to assess plausible futures for global EV markets and the implications they could have. The scenarios do not make predictions about the future. Rather, they aim to provide insights to inform decision-making by governments, companies and stakeholders about the future of EVs.

These scenario projections incorporate GDP and population assumptions from the International Monetary Fund (2022) and United Nations (2022), respectively.

Stated Policies Scenario

The Stated Policies Scenario (STEPS) reflects existing policies and measures, as well as firm policy ambitions and objectives that have been legislated by

[1] The projections in the Stated Policies and Announced Pledges scenarios are based on historical trends through the end of 2022 as well as stated policies and ambitions as of the end of March 2023. The Net Zero Emissions by 2050 Scenario is consistent with the World Energy Outlook 2022 publication.

governments around the world. It includes current EV-related policies, regulations and investments, as well as market trends based on the expected impacts of technology developments, announced deployments and plans from industry stakeholders. The STEPS aims to hold up a mirror to the plans of policy makers and illustrate their consequences.

Announced Pledges Scenario

The Announced Pledges Scenario (APS) assumes that all announced ambitions and targets made by governments around the world are met in full and on time. With regards to electromobility, it includes all recent major announcements of electrification targets and longer-term net zero emissions and other pledges, regardless of whether these have been anchored in legislation or in updated Nationally Determined Contributions (NDCs). For example, the APS assumes that countries that have signed on to the Conference of the Parties (COP 26) declaration on accelerating the transition to 100% zero emissions cars and vans will achieve this goal, even if there are not yet policies or regulations in place to support it. In countries that have not yet made a net zero emissions pledge or set electrification targets, the APS considers the same policy framework as the STEPS. Non-policy assumptions for the APS, including population and economic growth, are the same as in the STEPS.

The difference between the APS and the STEPS represents the “implementation gap” that exists between the policy frameworks and measures required to achieve country ambitions and targets, and the policies and measures that have been legislated.

Net Zero Emissions by 2050 Scenario

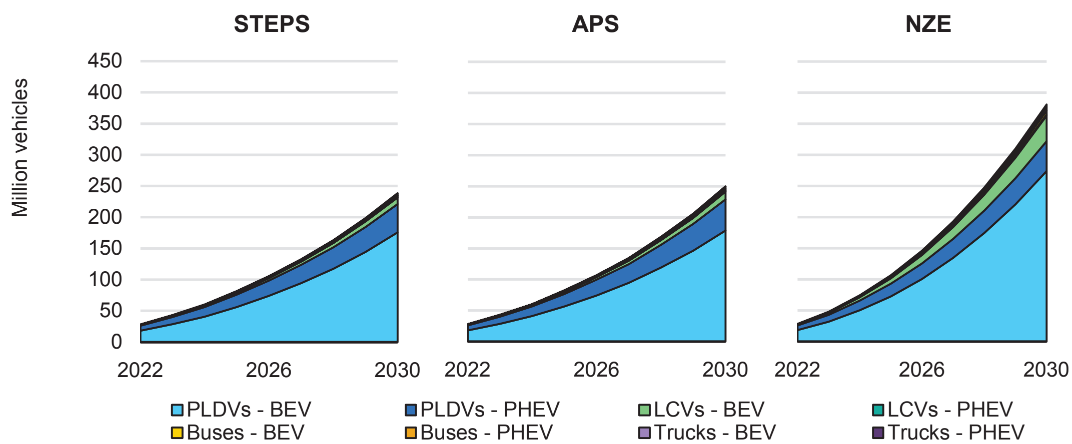
The Net Zero Emissions by 2050 Scenario (NZE Scenario) is a normative scenario that sets out a narrow but achievable pathway for the global energy sector to achieve net zero CO_2 emissions by 2050. The scenario is compatible with limiting the global temperature rise to 1.5°C with no or limited temperature overshoot, in line with reductions assessed by the Intergovernmental Panel on Climate Change in its Special Report on Global Warming of 1.5°C. There are many possible paths to achieve net zero CO_2 emissions globally by 2050 and many uncertainties that could affect them. The NZE Scenario is therefore *a* path and not *the* path to net zero emissions.

The difference between the NZE Scenario and the APS highlights the “ambition gap” that needs to be closed to achieve the goals under the 2015 Paris Agreement.

Electric vehicle fleet to grow by a factor of eight or more by 2030

The total fleet of EVs (excluding two/three-wheelers) grows from almost 30 million in 2022 to about 240 million in 2030 in the Stated Policies Scenario (STEPS), achieving an average annual growth rate of about 30%. In this scenario, EVs account for over 10% of the road vehicle fleet by 2030. Total EV sales reach over 20 million in 2025 and over 40 million in 2030, representing over 20% and 30% of all vehicle sales, respectively.

Figure 3.1. Electric vehicle stock by mode and scenario, 2022-2030

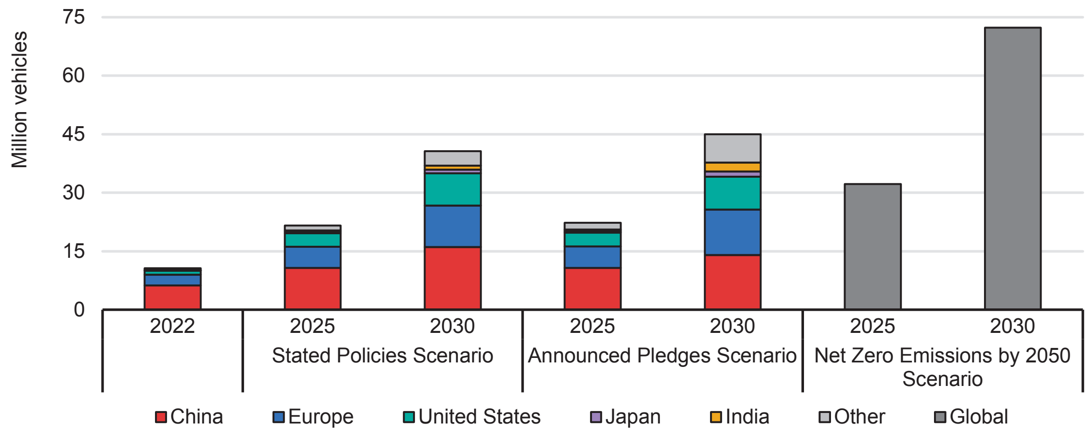


Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; BEV = battery electric vehicle; PHEV = plug-in hybrid electric; PLDV = passenger light-duty vehicle; LCV = light commercial vehicle.

EV deployment commensurate with government pledges is only 5% above what stated policies would imply by 2030.

In the Announced Pledged Scenario (APS), based on announced government targets and pledges that go beyond existing policies, the global EV fleet reaches almost 250 million in 2030, around 5% higher than in the STEPS. The average annual growth rate in the APS is nearly 35%, with the result that one in seven vehicles on the road is an EV in 2030. Total EV sales reach 45 million in 2030, representing over 35% of all vehicle sales.

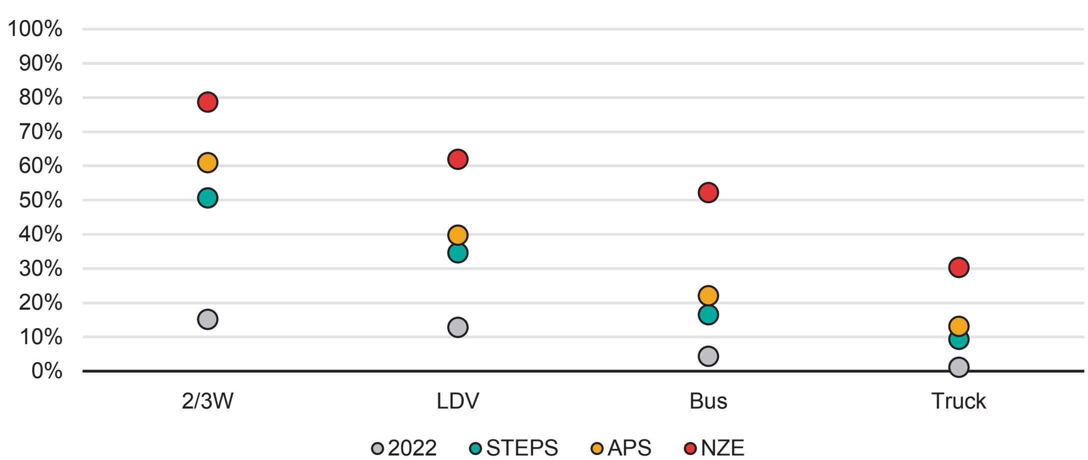
Figure 3.2. Electric vehicle sales by region, 2022-2030



Global EV sales increase around fourfold from 2022 to 2030 under both stated policies and announced ambitions.

The global EV sales share in 2030 in the STEPS is about half that in the NZE Scenario, in which the fleet of EVs grows more rapidly, at an average annual rate of around 40%, reaching 380 million EVs on the road in 2030. Electric vehicle sales reach over 30 million in 2025 and over 70 million in 2030, a total of approximately 30% and 60% of all vehicle sales, respectively.

Figure 3.3. Electric vehicle sales shares by mode and scenario, 2030



Notes: 2/3W = two/three-wheeler; LDV = light-duty vehicle; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario.

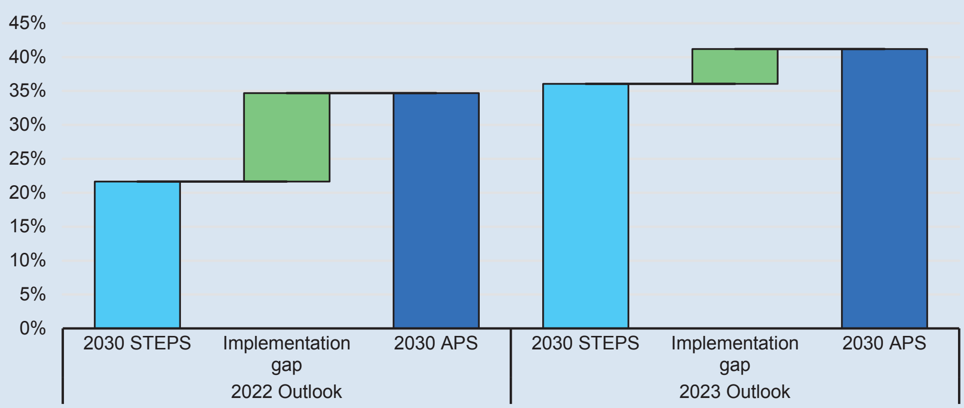
Existing policies are projected to yield market shares almost in line with country pledges across all modes of transport.

Box 3.1 Closing the implementation gap: how EV policy is catching up with targets

Targets and ambitions for clean energy technology deployment are generally more easily formulated than they are achieved, but in the case of EVs, the momentum is clearly on the side of achievement. Strong market uptake in 2022, combined with major policy announcements over the past year, have led to a significant upward revision of EV deployment to 2030 in the STEPS presented in this edition of the Global EV Outlook compared to the 2022 edition. The projected sales shares of EVs based on stated policies and market trends are now coming close to country stated ambitions for EVs, meaning that the policy implementation gap – the difference between country deployment ambitions and the policies currently in place – in the 2023 Outlook is much smaller than in the 2022 edition.

This is most notable for light-duty vehicles, where recent policies such as the US Inflation Reduction Act (IRA) and new EU CO_2 standards for cars and vans have resulted in a significantly higher EV sales share in 2030 in the STEPS. In this year's Outlook, under announced ambitions, the electric car sales share exceeds 40% in 2030 compared to 35% under stated policies: this gap has more than halved in the past year. For trucks and buses, the EV sales share in 2030 in the STEPS also increased faster than ambition. As a result, the gap between ambition and legislated policies for HDVs is half of what it was in the 2022 Outlook.

Electric car sales share implementation gap, 2030



Realising the potential of EVs to support government climate (as well as energy security) ambitions is thus almost in reach under current policy frameworks. In particular, the gap between policy and ambition has closed in three of the largest EV markets: the European Union, the United States and China. At the global level, oil displacement by EVs reaches 1.8 million barrels per day in 2025 (over 5 mb/d in 2030) under stated policies. As a result, global demand for oil-based road transport fuels will peak by 2025.

The momentum seen over the past year in terms of increasing EV sales and new supportive policies being introduced, along with funding designated for the necessary infrastructure (for example, the USD 5 billion allocated in the US IIJA to support EV charger installation), have also led industry players to invest more in EV supply chains. Notably, planned EV battery manufacturing expansions are set to increase capacity more than fourfold, reaching 6.8 TWh/year of production capacity in 2030, 65% higher than is needed to enable the level of EV deployment in the APS. Taken together, this suggests that even higher EV deployment than is implied by the APS is achievable by 2030 if policy efforts are sustained and critical potential bottlenecks (such as around recharging infrastructure and mining) are addressed early on.

Light-duty vehicles

Light-duty vehicles (LDVs), including passenger light-duty vehicles (PLDVs) and light commercial vehicles (LCVs), continue to make up the majority of electric vehicles (excluding two/three-wheelers). This is a result of strong policy support, including light-duty vehicle fuel economy or CO_2 standards, the availability of EV models, and the size of the LDV market. In the STEPS, electric LDV sales are projected to reach over 20 million in 2025, doubling the number of sales in 2022, and to quadruple to 40 million in 2030. The sales share of electric LDVs thus increases from 13% in 2022 to over 20% in 2025 and around 35% in 2030. The stock of electric LDVs reaches about 230 million in 2030, meaning that about one in every seven LDVs on the road is electric.

In the APS, the fleet of electric LDVs reaches over 240 million in 2030, a 15% stock share. Of these, 230 million are electric PLDVs, with only 6% being LCVs. Sales of electric LDVs reach almost 45 million in 2030 in the APS, representing a sales share of 40%. These results reflect government electrification ambitions and net zero pledges, including the 2021 COP 26 declaration target to achieve 100% zero-emission LDV sales by 2040, and by 2035 in leading markets, which 40 national governments have committed to.

In the NZE Scenario, the sales share of electric LDVs reaches 30% in 2025, four years earlier than in the STEPS. In 2030, the sales share is over 60%, about 80% higher than in the STEPS and 55% higher than in the APS.

Buses

Governments have made significant progress in electrifying public bus fleets. In 2022, there were more than 800 000 electric buses on the road, representing over 3% of all buses. As such, buses are the most electrified road segment, excluding two/three-wheelers. In the STEPS, the electric bus fleet reaches 1.4 million in 2025 and 2.7 million in 2030, at which point around one in ten buses will be electric. In the near term, electrification is expected to progress most rapidly within the publicly owned urban bus fleet, which is covered by government procurement regulations and, in some cases, government funding. For example, Canada is aiming to put 5 000 electric public and school buses on the road by the end of 2025 via the CAD 2.75 billion Zero Emission Transit Fund.

In the APS, the electric bus fleet exceeds 3 million in 2030, reaching a stock share of over 10%. In 2030, about a quarter of buses sold are electric, which is about 35% higher than the sales share in the STEPS. In part, this increase is due to the proposed EU heavy-duty vehicle CO_2 standards, which would require 100% zero-emission city bus sales from 2030. In the NZE Scenario, the electrification of buses is even more rapid, with one in two buses sold in 2030 being electric.

Medium- and heavy-duty trucks

Medium- and heavy-duty trucks are more difficult to electrify than other road segments, due in part to the size, weight and cost of the batteries needed to fully electrify this segment. However, progress is being made: around 320 000 electric trucks were on the road in 2022. By 2030, the fleet of electric trucks reaches almost 3.5 million in the STEPS, over 3% of the total truck fleet.

In the APS, the stock of electric trucks exceeds 4 million in 2030, a stock share of 4%. Electric truck sales increase from a negligible share today to over 9% in the STEPS in 2030 and 13% in the APS. The increased sales in the APS are driven in particular by the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles, through which 27 countries have now pledged to reach 30% zero-emission medium- and heavy-duty vehicle[2] sales by 2030 and 100% by 2040. In addition, the European Union has proposed HDV CO_2 standards that would require a 45% reduction in emissions in 2030 compared to 2019 levels.

In the NZE Scenario, electric trucks reach 30% of sales in 2030, which is aligned with the Global MoU on Zero-Emission Medium- and Heavy-Duty vehicles. However, this sales share is still two-and-a-half times that in the APS, and over three times that in the STEPS.

Two/three-wheelers

Two/three-wheelers are currently the most electrified road transport segment. Given the vehicles' light weight and limited daily driving distance, battery electrification is relatively easy and makes economic sense on a total cost of ownership basis in many regions. In 2022, the electric two/three-wheeler fleet totalled over 50 million, reaching a stock share of around 7%.

In the STEPS, the fleet of electric two/three-wheelers reaches 220 million in 2030, or a quarter of the total two/three-wheeler fleet. In the APS, the stock grows to 280 million, and almost 30% of all two/three-wheelers are electric. The electric sales share in 2030 reaches 50% in the STEPS and 60% in the APS. In the NZE Scenario, the electric two/three-wheeler sales share reaches almost 80% in 2030.

[2] Includes buses.

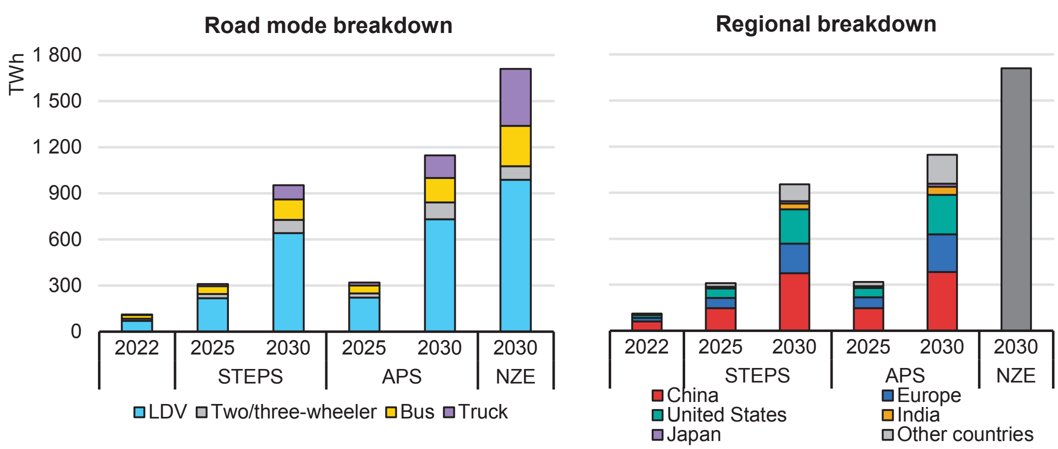
To power the growing stock of electric trucks, the number of depot chargers increases from around 300 000 today to 3.5 million in 2030 in the STEPS and 4.2 million in the APS. The installed capacity of truck depot chargers is about 310 GW in the STEPS and 380 GW in the APS in 2030. As with buses, the number of depot chargers needed in 2030 is far greater than the number of opportunity chargers. In the STEPS, the number of opportunity truck chargers is about 13 500 (6.5 GW installed capacity), increasing to 25 000 (13 GW installed capacity) in the APS in 2030.

Impact on energy demand and emissions

Electricity demand

The global EV fleet consumed about 110 TWh of electricity in 2022, which equates roughly to the current total electricity demand in the Netherlands. Almost a quarter of the total EV electricity consumption was for electric cars in China, and a fifth for electric buses in the same country. Electricity demand for EVs accounts for less than half a percent of current total final electricity consumption worldwide, and still less than one percent of China's final electricity consumption.

Figure 3.12. Electricity demand by mode and region, 2022-2030



Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; LDV = light-duty vehicle; RoW = rest of the world. The analysis is carried out for each region in the transport model within the IEA's Global Energy and Climate Model (GEC-Model) separately and then aggregated for global results. For the Net Zero Emissions by 2050 Scenario, only global values are reported. Regional data can be interactively explored via the Global EV Data Explorer.

Electricity demand for EVs accounts for only a minor share of global electricity consumption in 2030 in the Announced Pledges Scenario.

Electricity demand for EVs is projected to reach over 950 TWh in the STEPS and about 1 150 TWh in the APS in 2030. Notably, electricity demand in the APS is about 20% higher than in the STEPS, despite the stock of EVs only being about 15% higher. This is in part due to higher rates of electrification in many high-average vehicle mileage markets such as the United States, but also to greater electrification in the truck and bus segments, which contribute incrementally to vehicle stock, but have a high electricity demand per vehicle. In addition, it is assumed that in countries with net zero pledges, a larger share of energy consumption in PHEVs is provided by electricity (as opposed to gasoline or diesel). This is particularly relevant for cars and vans, which account for about two-thirds of demand in both scenarios.

By 2030, electricity demand for EVs accounts for less than 4% of global final electricity consumption in both scenarios. As shown in the World Energy Outlook 2022, in 2030 the share of electricity for EVs is relatively small compared to demand for industrial applications, appliances or cooling and heating.

Table 3.1 Share of electricity consumption from electric vehicles relative to final electricity demand by region and scenario, 2022 and 2030

Country/region	2022	Stated Policies Scenario 2030	Announced Pledges Scenario 2030
China	0.8%	3.8%	4.0%
Europe	0.7%	4.7%	5.7%
United States	0.4%	5.4%	6.3%
Japan	0.1%	1.7%	2.2%
India	0.1%	1.7%	2.5%
Global	0.5%	3.2%	3.8%

Note: Non-road electricity consumption from the World Energy Outlook 2022.

China remains the largest consumer of electricity for EVs in 2030, although its share of global EV electricity demand decreases significantly from about 55% in 2022 to less than 40% in the STEPS, and around 30% in the APS. This reflects wider adoption of electromobility across other countries in the period to 2030.

The size of the EV fleet becomes an important factor for power systems in both scenarios, with implications for peak power demand, transmission and distribution capacity. Careful planning of electricity infrastructure, peak load management, and smart charging will be critical. Reducing dependence on fast charging will allow for optimal planning and resiliency of power systems, mitigating peak power demand. More than 80% of the electricity demand for electric LDVs in 2030 in both scenarios is via slow chargers (private and public).

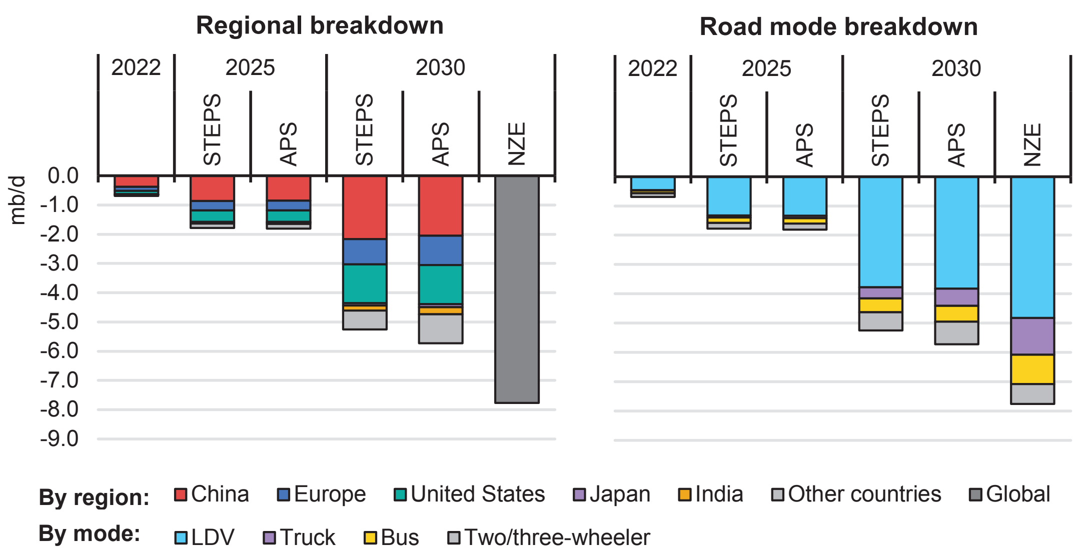
To help policy makers prioritise charging strategies according to the size of their EV fleet and their power system configuration, the IEA has developed a guiding framework and online tool for EV grid integration.

Oil displacement

The growing EV stock will reduce oil use, which today accounts for over 90% of total final consumption in the transport sector. Globally, the projected EV fleet in 2030 displaces more than 5 million barrels per day (mb/d) of diesel and gasoline in the STEPS and almost 6 mb/d in the APS, up from about 0.7 mb/d in 2022. For reference, Australia consumed around 1 mb/d of oil products across all sectors in 2021.

However, recent price volatility for critical minerals that are important inputs to battery manufacturing, and market tension affecting supply chains, are a stark reminder that in the transition to electromobility, energy security considerations evolve and require regular reconsideration.

Figure 3.13. Oil displacement by region and mode, 2022-2030



Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; LDV = light-duty vehicle. Oil displacement based on internal combustion engine (ICE) vehicle fuel consumption to cover the same mileage as the EV fleet.

Oil displacement increases from 0.7 mb/d in 2022 to nearly 6 mb/d in 2030 if pledges supporting electromobility in road transport around the world are fulfilled.

Box 3.2 How much oil really gets displaced by electric vehicles?

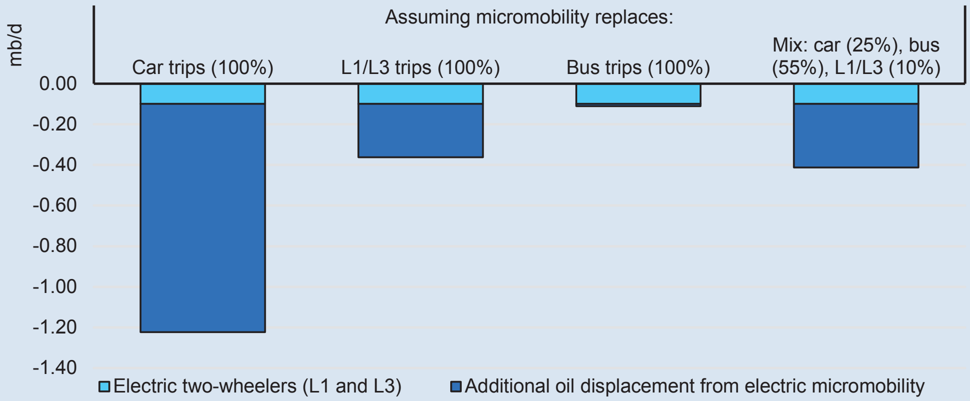
Oil displacement through the use of EVs can be estimated by assuming that the distance (total kilometres) travelled by EVs by segment each year would have otherwise been travelled by ICE vehicles or hybrid electric vehicles (HEVs) (based on the stock shares of each). In the case of PHEVs, only the distance covered by electricity gets included. The stock average fuel consumption of gasoline and diesel vehicles determines the total liquid fuel displacement, where the biofuel portion is taken out of the estimate based on regional blending rates. As a result, it can be estimated that in 2022, the stock of EVs displaced 700 000 barrels of oil per day.

This method of estimation assumes that EVs replace ICE or hybrid vehicles of the same segment, as opposed to some other means of transport, i.e. an electric car replaces an ICE car. The accuracy of this assumption is uncertain, in particular with respect to two-wheelers. In IEA analysis, only two-wheelers that fit the United Nations Economic Commission for Europe (UNECE) classification of L1 or L3 are considered. This definition excludes micromobility options such as electric-assisted bicycles and low-speed electric scooters, leading to a significantly lower stock (around 80% lower) than when including micromobility segments.

Whether or not electric micromobility avoids oil use is uncertain, as it might displace manual bicycles or walking rather than ICE two-wheelers. At the same time, there is evidence that in some cases micromobility displaces personal car or taxi trips. The estimate of the amount of oil use that is avoided by two-wheeled micromobility therefore strongly depends on the assumptions about the mode that is being displaced.

The case of China, which represents over 95% of the global stock of two-wheeled electric micromobility, is a good example. Assuming that all two-wheeled micromobility in China replaces conventional ICE two-wheelers would increase oil displacement by 260 kb/d (or 160%). If instead electric micromobility was assumed to replace only bus trips, then the total oil displacement from two-wheelers in China would increase by just 10 kb/d (10%). However, if it was assumed that they displaced car trips, then oil use avoided by two-wheelers in China would be more than 1 mb/d higher. Including oil displacement from the two-wheeled electric micromobility segment in China alone can therefore increase the estimated 2022 global oil displacement from all electric vehicles anywhere from 1% to 160%. But there is significant uncertainty as to whether any oil is displaced at all.

Additional two-wheeler oil displacement in China when accounting for micromobility segments, 2022



Notes: Electric L1 and L3 two-wheelers (based on UNECE classifications) are assumed to replace ICE two-wheelers. For this analysis, it is assumed micromobility two-wheelers travel on average 10 km/day. The mix shown is based on findings from an investigation of e-bike use in Kunming, China. The other 10% of the mix is assumed to replace active transport, and thus does not contribute to oil displacement.
Sources: IEA analysis based on BNEF and Cherry et al. (2016).

Tax revenues

Taxes on petroleum-based road fuels can be a significant source of income for governments, [7] and are often used to support investments in transport infrastructure, such as roads and bridges. Given the levels of oil displacement discussed above, the transition to EVs will reduce these tax revenues. Additional tax revenue from electricity will not be sufficient to fully compensate for this reduction, both because taxes on electricity tend to be lower on an energy basis and because EVs are more efficient and thus use less energy than ICE vehicles.

In 2022, the transition to electric vehicle stock displaced around USD 11 billion in gasoline and diesel tax revenues globally. At the same time, the use of EVs generated around USD 2 billion in electricity tax revenue, meaning there was a net loss of around USD 9 billion. Although China has the greatest stock of EVs, the greatest impact on tax revenues was seen in Europe, a trend which is expected to continue into the future. This is because Europe has some of the highest taxes on gasoline and diesel; for example, the gasoline tax rate in Germany is almost ten times the rate in China.

As the number of EVs increases globally, government fuel tax revenues are expected to decline, with global net tax losses increasing by around two-and-a-

[7] While the share of total government revenue from fuel taxes may be small, for example it has recently been less than 3% in the United Kingdom, in many cases it represents a large share of the budget allocations for transportation infrastructure.

https://www.jera.co.jp/en/news/information/20240401_1863

Start of Demonstration Testing of Fuel Ammonia Substitution at JERA's Hekinan Thermal Power Station: The World's First Demonstration Testing of 20% Ammonia Substitution at a Large-Scale Commercial Coal-Fired Thermal Power Plant

2024/04/01

JERA Co., Inc. ("JERA") and IHI Corporation ("IHI") are working together on the "Development of Technologies for Carbon Recycling and Next-Generation Thermal Power Generation / Research, Development, and Demonstration of Technologies for Ammonia Co-Firing Thermal Power Generation" project ("the Project"), subsidized by the New Energy and Industrial Technology Development Organization (NEDO). Under the Project, JERA and IHI today began, at JERA's Hekinan Thermal Power Station in Hekinan City, Aichi Prefecture, the world's first demonstration testing of large-volume fuel ammonia substitution (20% of heating value) at a large-scale commercial coal-fired thermal power plant. This demonstration testing is planned to be carried out through June 2024.

1. Background

Ammonia is an efficient, low-cost means of transporting and storing hydrogen. In addition to the role as an energy carrier, it can also be used directly as a fuel in thermal power generation. Because it does not emit carbon dioxide when burned, fuel ammonia has the major advantage of reducing greenhouse gas emissions. The Project*1 is important as it may offer a low-cost first step to quickly advance the decarbonization in countries like Japan that need thermal power generation as an adjustable power source to ensure a stable supply of energy.

2. Overview of Demonstration Testing

Looking to reduce future environmental impact, the Project aims to establish ammonia substitution technology by substituting fuel with ammonia at a large-scale commercial coal-fired power plant and evaluating both boiler heat absorption and environmental impact characteristics such as exhaust gases. The Project period is scheduled for approximately 4 years from July 2021 through March 2025.

Since October 2022, JERA and IHI have been moving forward in constructing the burners, tank, vaporizer, piping, and other facilities necessary for demonstration testing fuel ammonia substitution at JERA's Hekinan Thermal Power Station.

IHI has developed a test burner*2 based on the results of small-volume testing of fuel ammonia at the power station's Unit 5, and JERA has prepared safety measures and an operational framework for the use of fuel ammonia at the power station*3.

With such preparations in place, the demonstration testing of large-volume fuel ammonia substitution began today at the power station's Unit 4. The demonstration testing will look at characteristics of the plant overall, investigating nitrogen oxide (NOx) emissions and confirming factors such as operability and the impact on boilers and ancillary equipment.

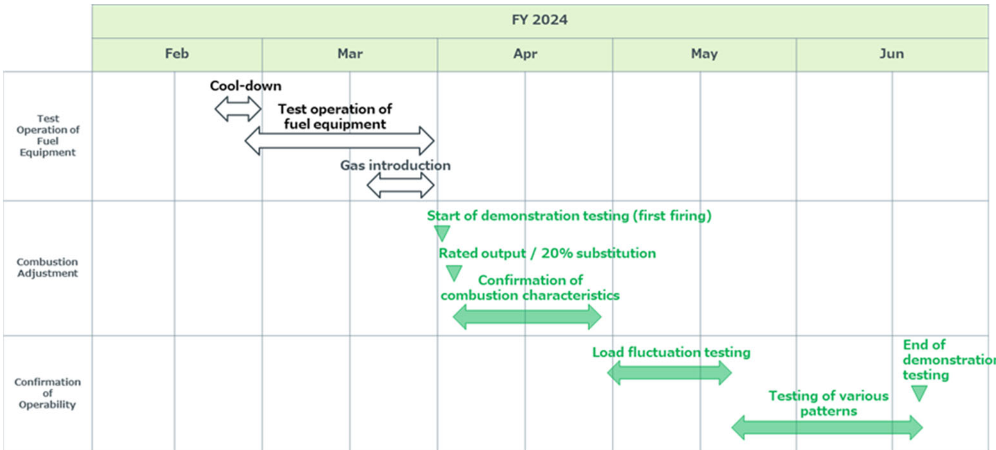


Figure 1: Demonstration Testing Schedule

Figure 2: Demonstration Testing Facilities(left ： Test burner)

3. Future Plans

JERA and IHI, by addressing issues raised through the demonstration testing, will seek to establish, technology for the use of fuel ammonia in thermal power generation with a view toward mainstreaming in society by March 2025.

Based on the current demonstration testing, JERA will begin commercial operation of large-volume fuel ammonia substitution (20% of heating value) at Unit 4 of JERA's Hekinan Thermal Power Station. By establishing the technology for ammonia substitution, JERA will offer a clean energy supply platform that combines renewable energy with low-carbon thermal power, contributing to the healthy growth and development of Asia and the world.

In addition to steadily carrying out the current demonstration testing, IHI will apply the knowledges gained through the Project to establish technology for high-ratio combustion of 50% ammonia or more at thermal power plants and to develop burners for 100% ammonia combustion, deploying the results of the demonstration testing to other thermal power plants in Japan and overseas will contribute to global decarbonization through fuel ammonia.

Notes:

*1 The Project

Project name: Development of Technologies for Carbon Recycling and Next-Generation Thermal Power Generation / Research, Development, and Demonstration of Technologies for Ammonia Co-Firing Thermal Power Generation

Project term: FY 2021–FY 2024

Project overview: Development of Technologies for Carbon Recycling and Next-Generation Thermal Power Generation

https://www.nedo.go.jp/english/activities/activities_ZZJP_100115.html

*2 Test Burner Development

(Ref.) IHI press release (6 October 2021)

https://www.ihi.co.jp/en/all_news/2021/resources_energy_environment/1197542_3360.html

*3 Fuel Ammonia Safety Measures and Operational Framework

(Ref.) JERA website (Japanese only)

https://www.jera.co.jp/corporate/business/thermal-power/list/hekinan/ammonia_safety https://www.japantimes.co.jp/environment/2024/04/01/energy/jera-ammonia-trial-starts/

Jera starts ammonia co-firing trial at coal power station

An ammonia tank at Jera's Hekinan thermal power station in Aichi Prefecture on March 13 | REUTERS

Apr 1, 2024

Jera said on Monday that it has begun a demonstration of co-firing 20% of ammonia with coal at its Hekinan thermal power station in Aichi Prefecture, in what it said is the world's first trial using a large amount of the gas at a major commercial plant.

Japan's top power generator initially planned to start the trial from Tuesday last week, but it was delayed for about a week, as the testing of equipment and other things required time to ensure safety.

The trial could move Japan, the world's fifth-biggest carbon dioxide emitter, a step closer to its goal of using ammonia and hydrogen in thermal power generation to aid in reaching its 2050 goal of carbon neutrality.

Environmentalists have criticized the move as a way to extend the life of dirty coal-fired power generation.

Jera, a joint venture between Tokyo Electric Power Co. and Chubu Electric Power, will conduct the trial, together with heavy machinery-maker IHI, for about three months to check characteristics of the plant overall, including nitrogen oxide emissions and the impact on boilers and ancillary equipment.

Ammonia is mainly made from hydrogen produced from natural gas and nitrogen from the air. It does not emit carbon dioxide when burned, but its production releases emissions if it is made with fossil fuels.

"Ammonia is an efficient, low-cost means of transporting and storing hydrogen," Jera said in a statement, adding other benefits include direct utilization as a fuel in thermal power generation.

"This project is important as it may offer a low-cost first step to quickly advance the decarbonisation in countries like Japan that need thermal power generation as an adjustable power source to ensure a stable supply of energy," Jera said.

Jera aims to start ammonia co-firing on a commercial basis at the Hekinan No. 4 unit as early as 2027, and a trial of replacing 50% of coal with ammonia at its No. 5 unit in around 2028.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Alternative Fuels Data Center

https://afdc.energy.gov/fuels/hydrogen-basics

Hydrogen Basics

Hydrogen (H_2) is an alternative fuel that can be produced from diverse domestic resources. Although the market for hydrogen as a transportation fuel is in its infancy, government and industry are working toward clean, economical, and safe hydrogen production and distribution for widespread use in fuel cell electric vehicles (FCEVs). Light-duty FCEVs are now available in limited quantities to the consumer market in localized regions domestically and around the world. The market is also emerging for buses, material handling equipment (such as forklifts), ground support equipment, medium- and heavy-duty trucks, marine vessels, and stationary applications. For more information, see fuel properties and the Hydrogen Analysis Resource Center.

Hydrogen is abundant in our environment. It's stored in water (H_2O), hydrocarbons (such as methane, CH_4), and other organic matter. One challenge of using hydrogen as a fuel is efficiently extracting it from these compounds.

Currently, steam reforming—combining high-temperature steam with natural gas to extract hydrogen—accounts for the majority of the hydrogen produced in the United States. Hydrogen can also be produced from water through electrolysis. This is more energy intensive but can be done using renewable energy, such as wind or solar, and avoiding the harmful emissions associated with other kinds of energy production.

Almost all the hydrogen produced in the United States each year is used for refining petroleum, treating metals, producing fertilizer, and processing foods.

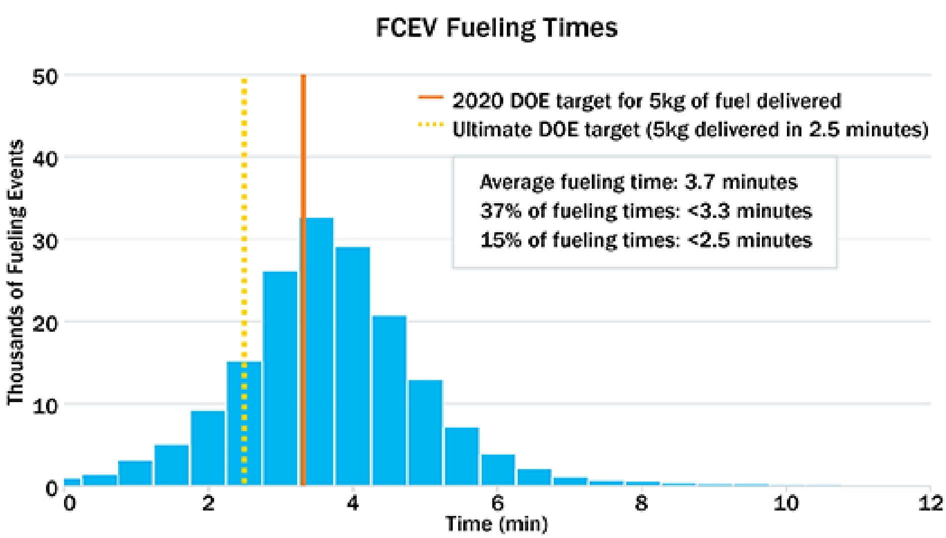
Although the production of hydrogen may generate emissions affecting air quality, depending on the source, an FCEV running on hydrogen emits only water vapor and warm air as exhaust and is considered a zero-emission vehicle. Major research and development efforts are aimed at making these vehicles and their infrastructure practical for widespread use. This has led to the rollout of light-duty vehicles to retail consumers, as well as the initial implementation of medium- and heavy-duty buses and trucks in California and fleet availability in northeastern states.

Learn more about hydrogen and fuel cells from the Hydrogen and Fuel Cell Technologies Office.

Hydrogen as an Alternative Fuel

Hydrogen is considered an alternative fuel under the Energy Policy Act of 1992. The interest in hydrogen as an alternative transportation fuel stems from its ability to power fuel cells in zero-emission vehicles, its potential for domestic production, and the fuel cell electric vehicle's fast filling time and high efficiency. In fact, a fuel cell coupled with an electric motor is two to three times more efficient than an internal combustion engine running on gasoline. Hydrogen can also serve as fuel for internal combustion engines. However, unlike FCEVs, these produce tailpipe emissions and are less efficient. Learn more about fuel cells.

The energy in 2.2 pounds (1 kilogram) of hydrogen gas is about the same as the energy in 1 gallon (6.2 pounds, 2.8 kilograms) of gasoline. Because hydrogen has a low volumetric energy density, it is stored onboard a vehicle as a compressed gas to achieve the driving range of conventional vehicles. Most current applications use high-pressure tanks capable of storing hydrogen at either 5,000 or 10,000 pounds per square inch (psi). For example, the FCEVs in production by automotive manufacturers and available at dealerships have 10,000 psi tanks. Retail dispensers, which are mostly co-located at gasoline stations, can fill these tanks in 3-5 minutes. Fuel cell electric buses currently use 5,000 psi tanks that take 10–15 minutes to fill. Other ways of storing hydrogen are under development, including bonding hydrogen chemically with a material such as metal hydride or low-temperature sorbent materials. Learn more about hydrogen storage.



Data from retail hydrogen fueling stations, collected and analyzed by the National Renewable Energy Laboratory, show the average time spent fueling an FCEV is less than 4 minutes.

California is leading the nation in building hydrogen fueling stations for FCEVs. As of 2023, 52 retail hydrogen stations were open to the public in California, as well as one in Hawaii, and 45 more were in various stages of construction or planning in California. These stations are serving over 8,000 FCEVs. California continues to provide funding toward building hydrogen infrastructure through its Clean Transportation Program. The California Energy Commission is authorized to allocate up to $20 million per year through 2023 and is investing in an initial 100 public stations to support and encourage these zero-emission vehicles. In addition, retail stations are planned for some midwestern and northeastern states, with some of those already serving fleet customers.

Vehicle manufacturers are only offering FCEVs to consumers who live in regions where hydrogen stations exist. Non-retail stations in California and throughout the country also continue serving FCEV fleets, including buses. Multiple distribution centers are using hydrogen to fuel material-handling vehicles in their normal operations. In addition, several announcements have been made regarding the production of heavy-duty vehicles, such as line-haul trucks, that will require fueling stations with much higher capacities than existing light-duty stations. Find hydrogen fueling stations across the United States.

Energy
and the
Hydrogen Economy

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Abstract

Between production and use any commercial product is subject to the following processes: packaging, transportation, storage and transfer. The same is true for hydrogen in a “Hydrogen Economy”. Hydrogen has to be packaged by compression or liquefaction, it has to be transported by surface vehicles or pipelines, it has to be stored and transferred. Generated by electrolysis or chemistry, the fuel gas has to go through theses market procedures before it can be used by the customer, even if it is produced locally at filling stations. As there are no environmental or energetic advantages in producing hydrogen from natural gas or other hydrocarbons, we do not consider this option, although hydrogen can be chemically synthesized at relative low cost.

In the past, hydrogen production and hydrogen use have been addressed by many, assuming that hydrogen gas is just another gaseous energy carrier and that it can be handled much like natural gas in today’s energy economy. With this study we present an analysis of the energy required to operate a pure hydrogen economy. High-grade electricity from renewable or nuclear sources is needed not only to generate hydrogen, but also for all other essential steps of a hydrogen economy. But because of the molecular structure of hydrogen, a hydrogen infrastructure is much more energy-intensive than a natural gas economy.

In this study, the energy consumed by each stage is related to the energy content (higher heating value HHV) of the delivered hydrogen itself. The analysis reveals that much more energy is needed to operate a hydrogen economy than is consumed in today's energy economy. In fact, depending on the chosen route the input of electrical energy to make, package, transport, store and transfer hydrogen may easily double the hydrogen energy delivered to the end user. But precious energy can be saved by packaging hydrogen chemically in a synthetic liquid hydrocarbon like methanol or dimethylether DME. We therefore suggest modifying the vision of a hydrogen economy by considering not only the closed hydrogen (water) cycle, but also the closed carbon (CO_2) cycle. This could create the intellectual platform for the conception of a post-fossil fuel energy economy based on synthetic hydrocarbons. Carbon atoms from biomass, organic waste materials or recycled carbon dioxide could become the carriers for hydrogen atoms. Furthermore, the energy consuming electrolysis may be partially replaced by the less energy intensive chemical transformation of water and carbon to synthetic hydrocarbons. As long as the carbon comes from the biosphere ("biocarbon") the synthetic hydrocarbon economy would be as benign with respect to environment as a pure hydrogen economy. But the use of "geocarbons" from fossil sources should be avoided to uncouple energy use from global worming.

Table of Contents

1. Introduction

Hydrogen is a fascinating energy carrier. It can be produced from electricity and water. Its conversion to heat or power is simple and clean. When combusted with oxygen, hydrogen forms water. No pollutants are generated or emitted. The water is returned to nature where it originally came from. But hydrogen, the most common chemical element on the planet, does not exist in nature in its pure form. It has to be separated from chemical compounds, by electrolysis from water or by chemical processes from hydrocarbons or other hydrogen carriers. The electricity for the electrolysis may eventually come from clean renewable sources such as solar radiation, kinetic energy of wind and water or geothermal heat. Therefore, hydrogen may become an important link between renewable physical energy and chemical energy carriers.

Hydrogen has fascinated generations of people for centuries including visionary minds like Jules Vernes. A "Hydrogen Economy" is projected as the ultimate solution for energy and environment. Hydrogen societies have been formed for the promotion of this goal by publications, meetings and exhibitions. But has the physics also been properly considered?

Both the production and the use of hydrogen have attracted highest attention while the practical aspects of a hydrogen economy, Figure 1, are rarely addressed. Like any other product hydrogen must be packaged, transported, stored and transferred to bring it from production to final use. These ordinary market processes require energy.

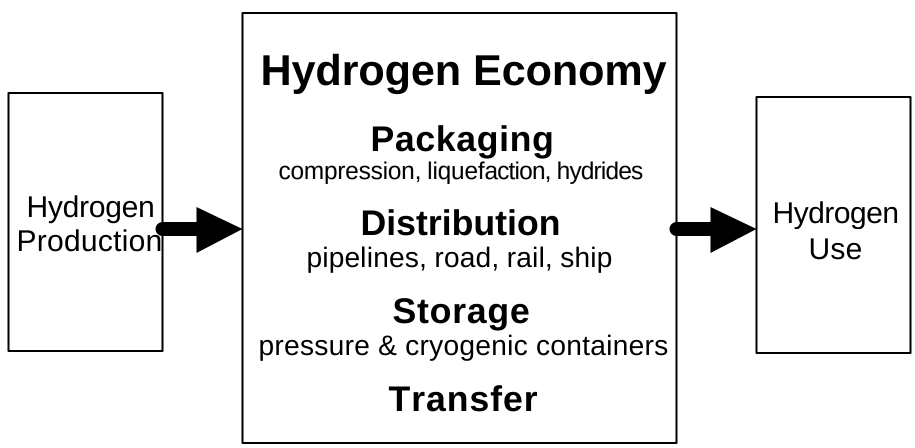

Figure 1 Schematic Presentation of a pure "Hydrogen Economy"

The energy lost in today's energy economy amounts to about 10% of the energy delivered to the customer. We would now like to present rough estimates of the energy required to operate a “Hydrogen Economy”.

Without question, technology for a hydrogen economy exists or can be developed. In fact, enormous amounts of hydrogen are generated, handled, transported and used in the chemical industry today. But this hydrogen is a chemical substance, not an energy commodity. Hydrogen production and transportation costs are absorbed in the price of the synthesized chemicals. The cost of hydrogen remains irrelevant as long as the final products find markets. Today, the use of hydrogen is governed by economic arguments and not by energetic considerations.

But if hydrogen is used as an energy carrier, energetic arguments must also be considered [1]. How much high-grade energy is used to make, to package, to handle, to store or to transport hydrogen? The global energy problem cannot be solved in a renewable energy environment, if the energy consumed to make and deliver hydrogen is of the same order as the energy content of the delivered fuel. But how much energy is consumed for compression, liquefaction, transportation, storage and transfer of hydrogen? Will there be only the hydrogen path in future? We have examined the key market procedures by physical reasoning and conclude that the future energy economy is unlikely to be based on pure hydrogen alone. Hydrogen will certainly be the main link between renewable physical and chemical energy, but most likely it will come to the consumer chemically packaged in the form of one or more synthetic consumer-friendly hydrocarbons.

Preliminary results of our study have already been presented at THE FUEL CELL WORLD conference in July 2002 [1].

2. Properties of Hydrogen

The physical properties of hydrogen are well known [2, 3]. It is the smallest of all atoms. Consequently, hydrogen is the lightest gas, about 8 times lighter than methane (representing natural gas). The gravimetric higher heating value "HHV" [4] of a fuel gas are of little relevance for practical applications. In general, the volume available for fuel tanks is limited, not only in automotive applications. Also, the diameter of pipelines cannot be increased at will. Therefore, for most practical assessments it is more meaningful to refer the energy content of fuel gases to a reference volume. Also, it is proper to use the higher heating value HHV (heat of formation) for this energy analysis, because it reflects the true energy content of the fuel based on the energy conservation principle (1st Law of Thermodynamics). By contrast, the lower heating value LLV is a technical standard created in the 19th century by boiler engineers confronted with problems of corrosion in the chimneys of coal-fired furnaces caused by condensation of sulfuric acid and other aggressive substances. Since the production of hydrogen is governed by the heat of formation or the higher heating value, its use should also be related to its HHV energy content. The following volumetric higher heating values for hydrogen and methane at 1 bar and 25°C will be used in this study.

	Dimensions	Hydrogen	Methane
Density at NTP	kg/m^3	0.09	0.72
Gravimetric HHV	MJ/kg	142.0	55.6
Volumetric HHV	MJ/m^3	12.7	40.0

Figure 2 shows the volumetric HHV energy densities of different energy carrier options. At any pressure, hydrogen gas clearly carries less energy per volume than methane (representing natural gas), methanol, propane or octane (representing gasoline). At 800 bar pressure gaseous hydrogen reaches the volumetric energy density of liquid hydrogen. But at any pressure, the volumetric energy density of methane gas exceeds that of hydrogen gas by a factor of 3.2 (neglecting non-ideal gas effects). The common liquid energy carriers like methanol, propane and octane (gasoline) surpass liquid hydrogen by factors 1.8 to 3.4, respectively. But at 800 bar or in the liquid state hydrogen must be contained in hi-tech pressure tanks or in cryogenic containers, while the liquid fuels are kept under atmospheric conditions in unsophisticated containers.

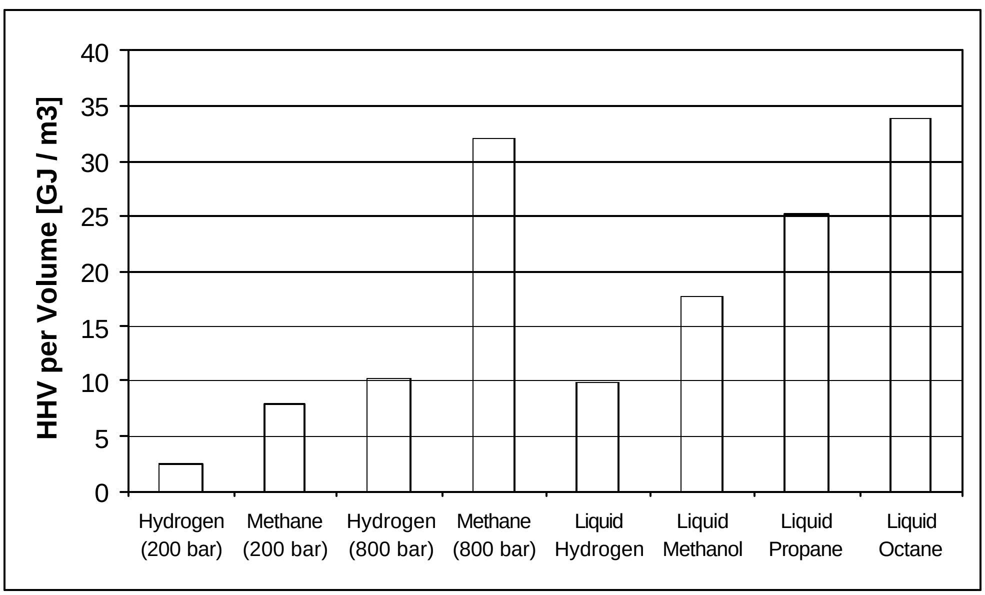

Figure 2 Volumetric HHV energy density of different fuels

3. Energy Needs of a Hydrogen Economy

Hydrogen is a synthetic energy carrier. It carries energy generated by some other processes. Electrical energy is transferred to hydrogen by electrolysis of water. But high-grade electrical energy is used not only to produce hydrogen, but also to compress, liquefy, transport, transfer or store the medium. In most cases the electrical energy could be distributed directly to the end user. For all stationary application hydrogen competes with grid electricity. Furthermore, liquid synthetic hydrocarbons could also serve as the general energy carrier of the future. Carbon from biomass or CO_2 captured from flue gases could become the carrier for hydrogen atoms generated with electrical energy from renewable or nuclear sources. There are environmentally benign alternatives to hydrogen.

Certainly, the cost of hydrogen should be as low as possible. But the hydrogen economy can establish itself only if it makes sense energetically. Otherwise, better solutions will conquer the market. Also, infrastructures exist for almost any synthetic liquid hydrocarbon, while hydrogen requires a totally new distribution network. The transition to a pure hydrogen economy will affect the entire energy supply and distribution system. Therefore, all aspects of a hydrogen economy should be discussed before investments are made.

The fundamental question: "How much energy is needed to operate a hydrogen economy?" will be analyzed in detail. We consider the key elements of a hydrogen economy like production, packaging, transport, storage and transfer of pure hydrogen and relate the energy consumed for these functions to the energy content of the delivered hydrogen. Our analysis is based on physics and verified by numbers obtained from the hydrogen industry. Throughout the study, only representative technical solutions will be considered.

4. Production of Hydrogen

4.1 Electrolysis

Hydrogen does not exist in nature in its pure state, but has to be produced from sources like water and natural gas. The synthesis of hydrogen requires energy. Ideally, the energy input equals the energy content of the synthetic gas. Hydrogen production by any process, e.g. electrolysis, reforming or else, is a process of energy transformation. Electrical energy or chemical energy of hydrocarbons is transferred to chemical energy of hydrogen. Unfortunately, the process of hydrogen production is always associated with energy losses.

Making hydrogen from water by electrolysis is one of the worst energy-intensive ways to produce the fuel. It is a clean process as long as the electricity comes from a clean source. But electrolysis is associated with losses. Electrolysis is the reversal of the hydrogen oxidation reaction the standard potential of which is about 1.23 Volts at NPT conditions. But electrolyzers need higher voltage to separate water into hydrogen and oxygen. The over-potential is needed to overcome polarization and ohmic losses caused by electric current flow under operational conditions.

The electrolyzer and fuel cell characteristics are schematically shown in Figure 3. Under open circuit conditions the electrochemical potential is 1.23 Volts at 20°C.

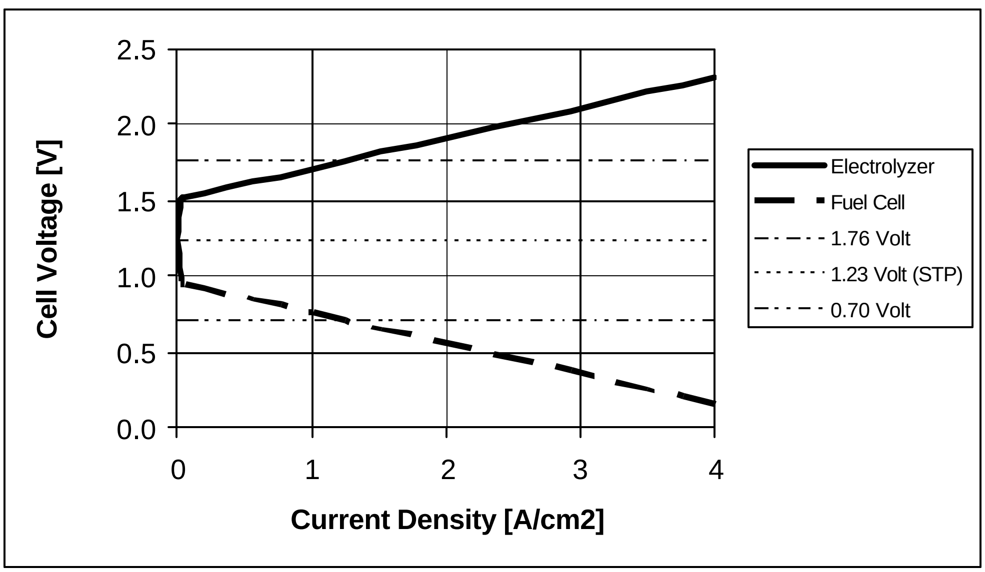

Figure 3 Voltage-current characteristics of electrolyzer and fuel cell.

Assuming that the same electrolyte and catalysts are used, the polarization losses are typically 0.28 Volt for solid polymer or alkaline systems. The apparent open circuit voltages thus become 0.95 and 1.51 Volt for fuel cell and electrolyzer, respectively. For both we assume an area-specific resistance of 0.2 Wcm^2 and construct the characteristics for a low temperature fuel cell (dashed line) and a corresponding electrolyzer (solid line).

Fuel cells are normally operated at 0.7 Volt to optimize the system efficiency. We assume the same optimization requirements also hold for an electrolyzer. In this case the corresponding voltage of operation is 1.76 Volts as indicated by the dash-dot lines in Figure 3.

The standard potential of 1.23 Volts corresponds to the higher heating value HHV of hydrogen. Consequently, the over-potential is a measure of the electrical losses of the functioning electrolyzer. The losses depend on the current density or the hydrogen production rate. As shown in Figure 4, at 1.76 Volt 1.43 energy units must be supplied for every HHV energy unit contained in the liberated hydrogen. At higher hydrogen production rates (higher current densities) this number increases further.

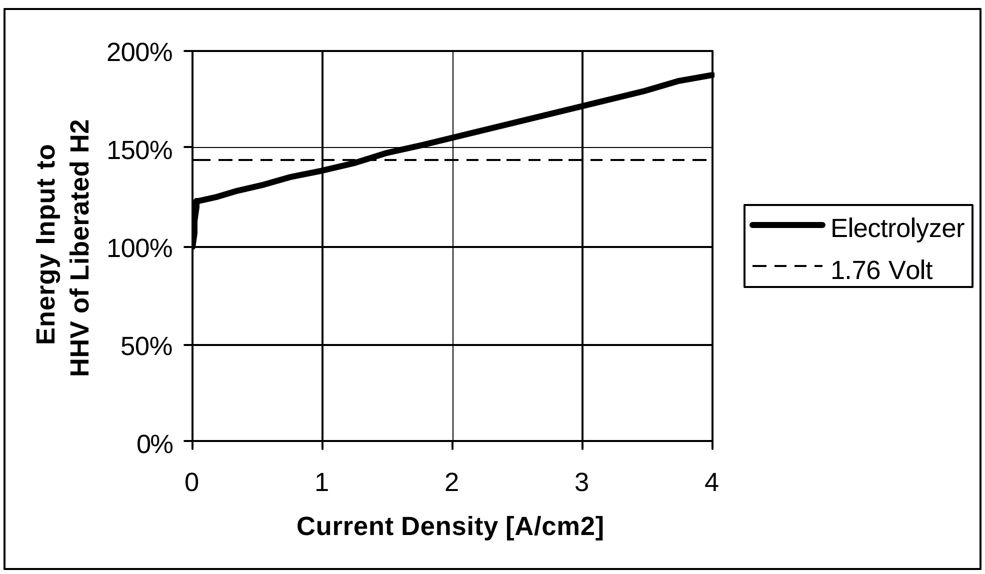

Figure 4 Energy input to electrolyze water compared to HHV energy of liberated hydrogen.

4.2 Reforming

Hydrogen can also be extracted from hydrocarbons by reforming. This chemical process is, in principle, an energy transfer process. The HHV energy contained in the original substance can be transferred to the HHV energy of hydrogen. Theoretically, no external energy is needed to convert a hydrogen-rich energy carrier like methane (CH_4) or methanol (CH_3OH) into hydrogen by autothermal steam reforming.

But in reality, thermal losses cannot be avoided and the HHV energy content of the original hydrocarbon fuel always exceeds the HHV energy contained in the generated hydrogen. The efficiency of hydrogen production by reforming is about 90%. Consequently, more CO_2 is released by this "detour" process than by direct use of the hydrocarbon precursors. But no obvious advantages can be derived with respect to well-to-wheel efficiency and overall CO_2 emissions.

For most practical application natural gas can do what hydrogen also does. There is no need for a conversion of natural gas into hydrogen which, as shown in this study, is more difficult to package and distribute than the natural energy carrier. The source energy (electricity or hydrocarbons) could be used directly by the consumer at comparable or even higher source-to-service efficiency and lower overall CO_2 emission. Upgrading electricity or natural gas to hydrogen does not provide a universal solution to the energy future, although some sectors of the energy market may prefer hydrogen. Fleet operation of vehicles may be one such application.

At today's energy prices, it is considerably more expensive to produce hydrogen by water electrolysis than by reforming of fossil fuels. According to [5] it costs around $5.60 for every GJ of hydrogen energy produced from natural gas, $10.30 per GJ from coal, and $20.10 per GJ to produce hydrogen by electrolysis of water.

5. Packaging of Hydrogen

5.1 Compression of Hydrogen

Energy is needed to compress gases. The compression work depends on the thermodynamic compression process. The ideal isothermal compression cannot be realized. The adiabatic compression equation [6]

$$W = [?/(? -1)]\ p_0\ V_o\ [(p_1/p_0)^{(? -1)/?} - 1] \qquad (1)$$

with	W	[J/kg]	specific compression work
	p_0	[Pa]	initial pressure
	p_1	[Pa]	final pressure
	V_0	[m^3/kg]	initial specific volume
	?	[-]	ratio of specific heats, adiabatic coefficient

is more closely describing the thermodynamic process for ideal gases. The compression work depends on the nature of the gas. This is illustrated by the comparison of hydrogen with helium and methane in Figure 5:

H_2	? = 1.41	V_0 = 11.11 m^3/kg
He	? = 1.66	V_0 = 5.56 m^3/kg
CH_4	? = 1.31	V_0 = 1.39 m^3/kg

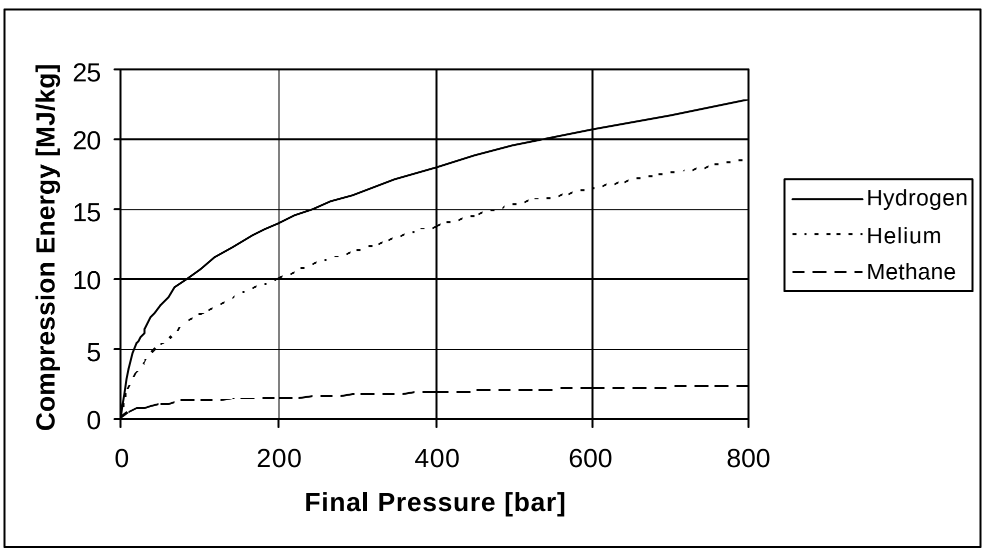

Figure 5 Adiabatic compression work for hydrogen, helium and methane

The energy consumed by an adiabatic compression of monatomic Helium, diatomic hydrogen and five-atomic methane from atmospheric conditions (1 bar = 100,000 Pa) to higher pressures is shown in Figure 2. Clearly, much more energy per kg is required to compress hydrogen than methane.

Isothermal compression follows a simpler equation:

$$W = p_0 V_0 \ln(p_1/p_0)$$

The same result is derived from the Nernst equation for the pressure electrolysis of water. In both cases, the compression work is the difference between the final and the initial energy state of the hydrogen gas.

Figure 6 illustrates the difference between adiabatic and isothermal ideal-gas compression of hydrogen. Multi-stage compressors with intercoolers operate between these two limiting curves. Also, hydrogen readily passes compression heat to cooler walls, thereby approaching isothermal conditions. Numbers provided by a leading manufacturer [7] of hydrogen compressors show that the energy invested in the compression of hydrogen is about 7.2% of its higher heating value (HHV). This number relates to a 5-stage compression of 1,000 kg of hydrogen per hour from 1 to 200 bar. For a final pressure of 800 bar the compression energy requirements would amount to about 13% of the energy content of hydrogen. This analysis does not include electrical losses in the power supply system.

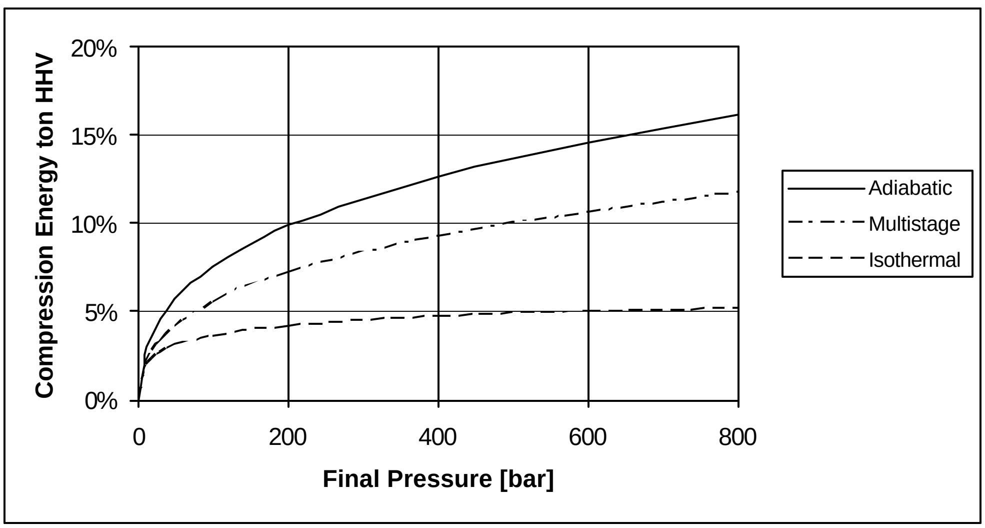

Figure 6 Energy required for the compression of hydrogen compared to its higher heating value HHV.

5.2 Liquefaction of Hydrogen

Even more energy is needed to compact hydrogen by liquefaction. Theoretically only about 3.6 MJ/kg have to be removed to cool hydrogen down to 20K (-253°C) and another 0.46 MJ/kg to condense the gas under atmospheric pressure. About 4 MJ/kg are removed from room temperature hydrogen gas in the process, little compared to its energy content of 142 MJ/kg. But cryogenic refrigeration is a complex process involving Carnot cycles and physical effects (e.g. Joule-Thomsen) that do not obey the laws of heat engines. Nevertheless, the Carnot efficiency is used as a reference for the foregoing process analysis. For the refrigeration between room temperature (T_R = 25°C = 298 K) and liquid hydrogen temperature (T_L = -253°C = 20 K) one obtains a Carnot efficiency of

$$?_c = T_L / (T_R - T_L) = 20 \text{ K} / (298 \text{ K} - 20 \text{ K}) = 0.072$$

or about 7%. The assumed single-step Carnot-type cooling process would consume at least 57 MJ/kg or 40% of the HHV energy content of hydrogen. This simple analysis does not include mechanical, thermal, flow-related or electrical losses in the multi-stage refrigeration process. But by intelligent process design the Carnot limitations may be partially removed. But the lower limit of energy consumption of a liquefaction plant does not drop much below 30% of the higher heating value of the liquefied hydrogen.

As a theoretical analysis of the complicated, multi-stage liquefaction processes is difficult, we present the energy consumption of existing hydrogen liquefaction plants [8].

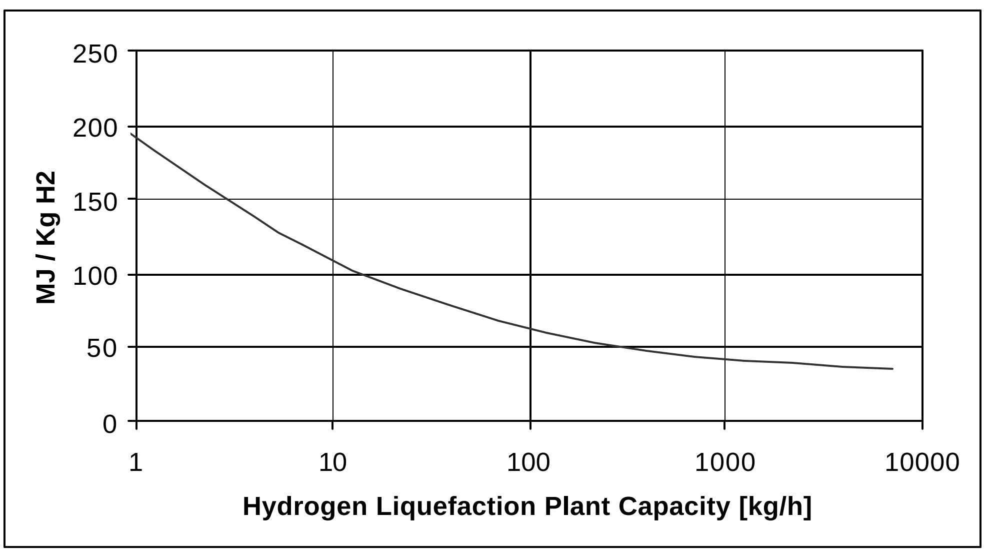

Figure 7 Typical energy requirements for the liquefaction of 1 kg hydrogen as a function of plant size and process optimization

The compilation reveals the following. Small (10 kg/h) liquefaction plants need about 100 MJ/kg, while large plants of 1000 kg/h or more capacity consume about 40 MJ of electrical energy for each kg liquefied hydrogen. The actual liquefaction energy consumption for plants between 1 to 10,000 kg/h capacity is shown in Figure 7. The specific energy input decreases with plant size, but a minimum of about 40 MJ per kg H_2 remains.

In Figure 8 the required energy input is compared to the higher heating value HHV of hydrogen. For small liquefaction plants the energy needed to liquefy hydrogen may exceed the HHV of the gas. But even with the largest plants (10,000 kg/h) at least 30% of the HHV energy is needed for the liquefaction process.

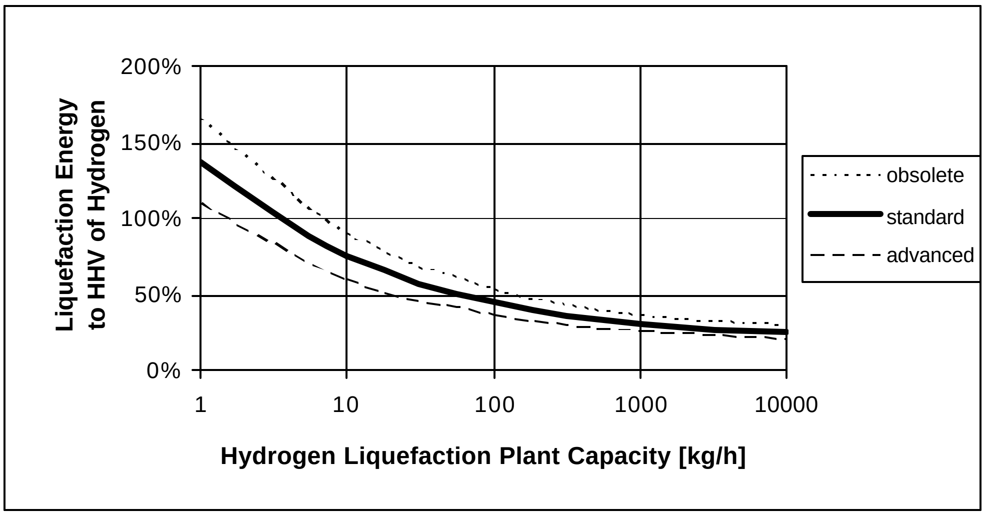

Figure 8 Actual energy requirement for the liquefaction of 1 kg hydrogen compared to HHV of hydrogen

5.3 Physical Packaging of Hydrogen in Hydrides

At this time only a generalized assessment can be presented for the physical (e.g. adsorption on metal hydrides) storage of hydrogen in spongy matrices of special alloys like $LaNi_5$ or $ZrCr_2$. Hydrogen is stored by physical/chemical adsorption, i.e. by a very close, but not perfect bond between hydrogen atoms and the storage alloys. Heat is released when a hydrogen storage container is filled. The release of hydrogen at lower pressure is driven by an influx of heat proportional to the hydrogen liberation rate. According to [9] metal hydrides store only around 55-60 kgH_2/m^3 compared to 70 kgH_2/m^3 for liquid hydrogen. But 100 kg of hydrogen are contained in one cubic meter of methanol.

The energy balance shall be described in general terms. Again, energy is needed to produce and compress hydrogen. Some of this energy input is lost in form of waste heat. When hydrogen is released heat must be added. No additional heat is required for small liberation rates and for containers designed for efficient heat exchange with the environment. Also waste heat from the fuel cell may be used to heat the hydrogen storage cartridge.

One may wish to consider the transport energy for the heavy metal hydride cartridges. Not even two grams of hydrogen can be stored in a small 230 g metal hydride cartridge. This makes this type of hydrogen packaging impractical for automotive applications.

But the energy needed to package hydrogen in physical metal hydrides is more or less limited to the energy needed to produce and compress hydrogen to 30 bar pressure. The energy cost of hydrogen delivered to the customer in physical metal hydrides is thus lower than of compressed hydrogen gas delivered at 200 bar pressure.

5.4 Chemical Packaging of Hydrogen in Hydrides

Hydrogen may also be stored chemically in alkali metal hydrides. There are many options in the alkali group like LiH, NaH, KH, CaH_2. But also complex binary hydride compounds like $LiBH_4$, $NaBH_4$, KBH_4, $LiAlH_4$ or $NaAH_4$ are of interest and have been proposed as hydrogen sources. None of these compounds can be found in nature. All have to be synthesized from metals and hydrogen.

Let us consider the case of calcium hydride CaH_2. The compound is produced by combining pure calcium metal with pure hydrogen at 480°C. Energy is needed to extract calcium from calcium carbonate (lime stone) and hydrogen from water by the following endothermic processes

$CaCO_3 \rightarrow Ca + CO_2 + 1/2\ O_2$	+ 808 kJ/mol
$H_2O \rightarrow H_2 + 1/2\ O_2$	+ 286 kJ/mol

Some of the energy is recovered when the two elements are combined at 480°C by an exothermic process

$Ca + H_2 \rightarrow CaH_2$	- 192 kJ/mol

The three equations combine to the virtual net reaction

$CaCO_3 + H_2O \rightarrow CaH_2 + CO2 + O_2$	+ 902 kJ/mol

Similarly, one obtains for the production of NaH and LiH from NaCl or LiCl

$NaCl + 0.5\ H_2O \rightarrow NaH + Cl + 0.25\ O_2$	+ 500 kJ/mol

and

$LiCl + 0.5\ H_2O \rightarrow LiH + Cl + 0.25\ O_2$	+ 460 kJ/mol

The material is then cooled under hydrogen to room temperature, granulated and packaged in airtight containers.

The hydrides react with water vividly under release of heat and hydrogen.

$CaH_2 + 2\ H_2O \rightarrow Ca(OH)_2 + 2\ H_2$	- 224 kJ/mol
$NaH + H_2O \rightarrow NaOH + H_2$	- 85 kJ/mol
$LiH + H_2O \rightarrow LiOH + H_2$	- 111 kJ/mol

In fact, the reaction of hydrides with water produces twice the hydrogen contained in hydride itself. Apparently, water is reduced while the hydride is oxidized to hydroxide. The generated heat has to be removed by cooling and is lost in most cases. For the three representative hydrides the energy balances are tabulated.

Hydride production from		Ca-Hydride $CaCO_3$	Na-Hydride NaCl	Li-Hydride LiCl
Energy to make hydride	kJ/mol	902	500	460
H_2 liberated from hydride	mol/mol	2	1	1
Production of H_2	g/mol	4	2	2
Energy input / H_2	kJ/g	225	250	230
=	MJ/kg	225	250	230
HHV of H_2	MJ/kg	142	142	142
Energy input / HHV of H_2	-	1.59	1.76	1.62

The results of this analysis are presented in Figure 9. The energy losses associated with the electrolytic decomposition of water, NaCl and LiCl have not even been considered.

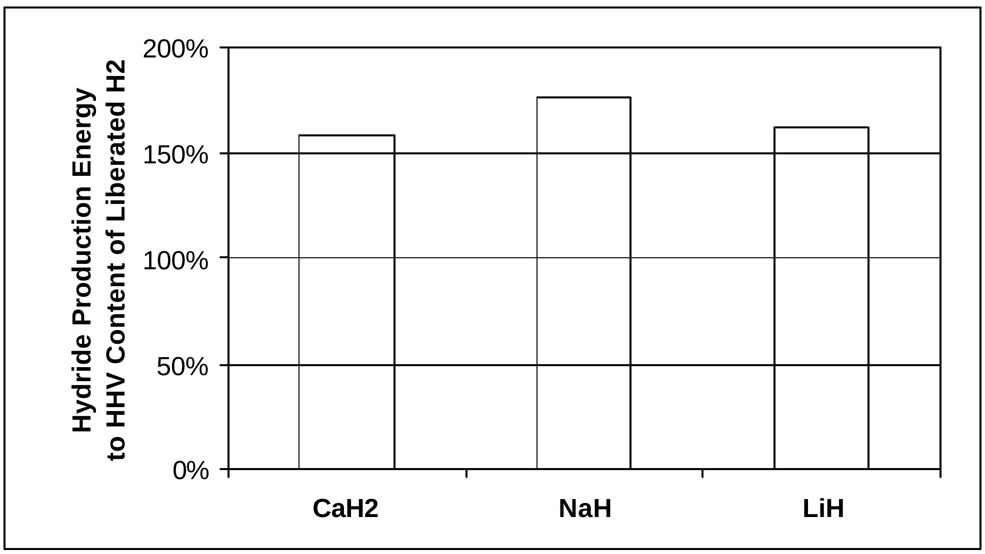

Figure 9 Energy needed to produce hydrides relative to HHV content of the liberated hydrogen

At least 160% of the HHV energy content of the librated hydrogen has to be invested to produce the hydrides. The chemical packaging of hydrogen in alkali metal hydrides will therefore remain a solution for a limited number of practical applications. at least 60% of the input energy is lost in the process.

6. Delivery of Hydrogen

6.1 Road Delivery of Hydrogen

A hydrogen economy also involves hydrogen transport by trucks and ships. There are other options for hydrogen distribution, but road transport will always play a role, be it to serve remote locations or to provide back-up fuel to filling stations at times of peak demand.

The comparative analysis is based on information obtained from the fuel and gas transport companies Messer-Griesheim [10], Esso (Schweiz) [11], Jani GmbH [12] and Hover [13] some of the leading providers of industrial gases in Germany and Switzerland. The following assumptions are made: Hydrogen (at 200 bar), liquid hydrogen, methanol, propane and octane (representing gasoline) are trucked from the refinery or hydrogen plant to the consumer. Trucks with a gross weight of 40 tons (30 tons for liquid hydrogen) are fitted with suitable tanks or pressure vessels. Also, at full load 40 kg of Diesel are consumed per 100 km. This is equivalent of 1 kg per ton per 100 km. The fuel consumption is reduced accordingly for the return run with emptied tanks. We assume the same engine efficiency for all transport vehicles.

While in most cases the transport is weight-limited, it is limited by volume for liquid hydrogen as shown by the following sample. The useful volume of a large moving van, a box 2.4 m wide, 2.5 m high and 10 m long, is 60 m^3. But only 4.2 tons of liquid hydrogen can be filled into this box, because the density of the cold liquid is only 70 kg/m^3 or slightly more than that of heavy duty Styrofoam. But space is needed for container, thermal insulation, equipment etc. In fact, there is room for only about 2.1 tons of liquid hydrogen on a large-size truck. This makes trucking of liquid hydrogen expensive, because despite of its small payload, the vehicle has to be financed, maintained, registered, insured, and driven as any truck by an experienced driver. For the analysis we assume the gross weight of the liquid hydrogen carrier is only 30 tons.

Furthermore, hydrogen pressure tanks can be emptied only from 200 bar to about 42 bar to accommodate for the 40 bar pressure systems of the receiver. Such pressure cascades are standard praxis today. Otherwise compressors must be used to completely empty the content of the delivery tank into a higher-pressure storage vessel. This would not only make the gas transfer more difficult, but also require additional compression energy as discussed below. As a consequence, pressurized gas carriers deliver only 80% of their freight, while 20% of the load remains in the tanks and is returned to the gas plant.

Each 40-ton truck is designed to carry a maximum of fuel. For methanol and octane the tare load it is about 26 tons, for propane about 20 tons. At 200-bar pressure a 40-ton truck can carry 4 tons, but deliver only 3.2 tons of methane. Today, at 200 a pressure only 320 kg of hydrogen can be carried and only 288 kg are delivered by a 40-ton truck. This is a direct consequence of the low density of hydrogen, as well as the weight of the pressure vessels and safety armatures. In anticipation of technical developments, the analysis was performed for 4000 kg methane and 500 kg of hydrogen, of which 80% or 3200 kg and 400 kg, respectively, are delivered to the consumer. With this assumption, a dead weight of 39.6 tons has to be moved on the road to deliver 400 kg of hydrogen. On the return run a heavy empty hydrogen truck consumes more diesel fuel than a much lighter empty gasoline carrier. The numbers in the following tables have been obtained for a 100 km delivery distance.

	Units	H2 Gas	Liquid H2	Methanol	Propane	Gasoline
Pressure	bar	200	1	1	5	1
Weight to customer	kg	40000	30000	40000	40000	40000
Weight from customer	kg	39600	27900	14000	20000	14000
Delivered weight	kg	400	2100	26000	20000	26000
HHV of fuel	MJ/kg	141.9	141.9	23.3	50.4	48.1
HHV energy per truck	GJ	57	298	580	1007	1252
Relative to gasoline	-	0.045	0.238	0.464	0.805	1
Diesel consumed	kg	79.6	57.9	54	60	54
Diesel HHV energy	GJ	3.56	2.59	2.41	2.68	2.41
Energy consumed to HHV energy delivered	%	6.27	0.87	0.42	0.27	0.19
Relative to gasoline	-	32.5	4.5	2.2	1.4	1
H2-efficiency factor	-	0.7	0.7	1	1	1
HHV energy delivered	GJ/d	876	876	1252	1252	1252
No. of trucks for same no. of serviced cars	-	15.4	2.9	2.2	1.24	1

The results of this analysis are presented in Figure 10. The energy needed to transport any of the three liquid fuels is reasonably small. It remains below 3% of the HHV energy content of the delivered commodity for a one-way delivery distance of 500 km.

But at almost any distance the relative energy consumption associated with the delivery of pressurized hydrogen becomes unacceptable. About 32 times more diesel fuel is required to deliver in the form of gaseous hydrogen compared to liquid gasoline. This factor is only about 4.5 for liquid hydrogen, but recall how much energy is required to liquefy the carried energy in initially.

In our analysis we do not consider improvements of the fuel economy of both conventional engine and fuel cell vehicles. Today, the fuel economy of modern, clean Diesel engines is excellent, but does not quite reach the HHV fuel economy of fuel cells vehicles. In both cases, the economy can be significantly improved by hybrid systems, mainly due to regenerative breaking. But from well to wheel either fuel path leads to similar results with respect to energy and CO_2 emissions. As both technology offer potentials for improvements, no distinctive answer can be given at this time.

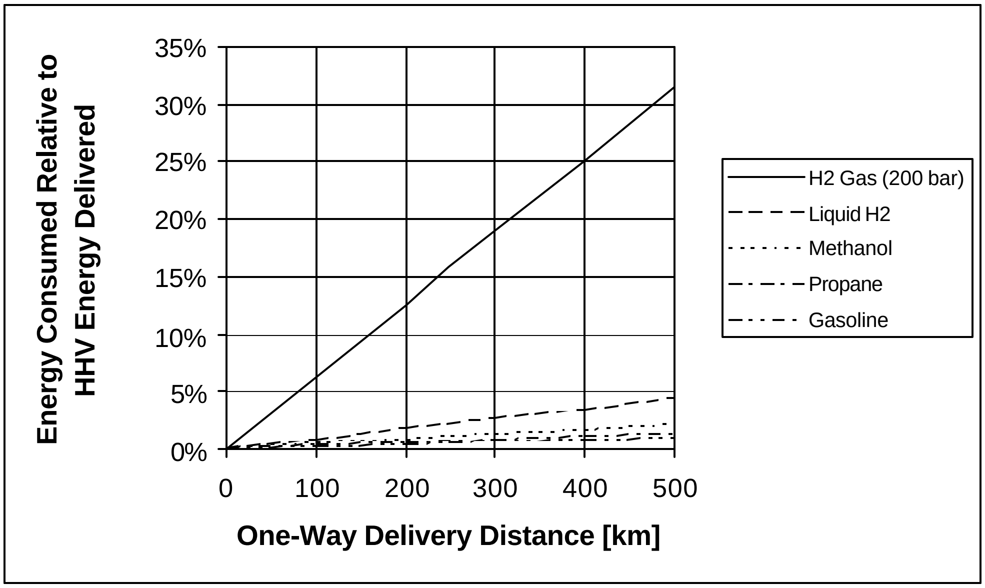

Figure 10 Energy needed for the road delivery of fuels compared to their HHV energy content

The following note may serve to illustrate the consequences of the scenario. A mid-size filling station on any major freeway easily sells 26 tons of gasoline each day. This fuel can be delivered by one 40-ton gasoline truck. Because of a potentially superior tank-to-wheel efficiency of fuel cell vehicles, we assume that hydrogen-fuelled vehicles need only 70% of the energy consumed by gasoline or Diesel vehicles to travel the same distance. Still, it would take 15 trucks to deliver compressed hydrogen (200 bar) energy to the station for the same daily amount of transport services, i.e. to provide fuel for the same number of passenger or cargo miles per day. Also, the transfer of pressurized hydrogen from those 15 trucks to the filling station takes much more time than draining gasoline from a single tanker into an underground storage tank. For safety reasons, hydrogen filling station may have to close down for some hours every day.

Today about one in 100 trucks is a gasoline or diesel tanker. For surface transportation of hydrogen one may see 115 trucks on the road, 15 or 13% of them transporting hydrogen. One out of seven accidents involving trucks would involve a hydrogen truck. Every seventh truck-truck collision would occur between two hydrogen carriers. This scenario is certainly unacceptable for many reasons.

6.2 Pipeline Delivery of Hydrogen

Hydrogen pipelines exist, but they are used to transport a chemical commodity from one to another production site. The energy required to move the gas has little is irrelevant, because energy consumption is part of the production costs. This is not so for hydrogen energy transport through pipelines. Normally, pumps are installed at regular intervals to keep the gas moving. These pumps are energized by energy taken from the delivery stream. About 0.3% of the natural gas is used every 150 km to energize a compressor to move the gas [14].

The assessment of the energy consumed to pump hydrogen through pipelines is derived from this natural gas pipeline operating experience. The comparison is done for equal energy flows. The same amount of energy is delivered to the customer through the same pipeline either contained in natural gas or hydrogen. In reality, existing pipelines cannot be used for hydrogen, because of diffusion losses, brittleness of materials and seals, incompatibility of pump lubrication with hydrogen and other technical issues. The comparison further considers the different viscosities of hydrogen and methane.

The theoretical pumping power N [W] requirement is given by

$$N = V_o\ ?p = A\ v\ ?p = p/4\ D^2\ v\ ?p = p/4\ D^2\ v\ 1/2\ ?\ v^2\ ? \qquad (2)$$

with $? = 0.31164 / Re^n$ (3)

and $Re = ?\ v\ D / ?$ (4)

The symbols have the following meaning:

V_o	volumetric flow rate [m^3/s]
A	cross section of pipe [m^2]
v	flow velocity of the gas [m/s]
?p	pressure drop [Pa]
D	pipeline diameter [m]
?	density of the gas [kg/m^3]
?	resistance coefficient
Re	Reynolds number
n	= 0.25 for turbulent pipe flow (Blasius equation) [15]
?	dynamic viscosity [kg/(m s)]

Furthermore, the flow of energy through the pipeline, Q [W] is given by

$$Q = V_o\ ?\ HHV \qquad (5)$$

with HHV being the higher heating value of the transported gas.

Combining equations (2), (3), (4) and (5) one can asses the theoretical pumping power N_{H2} for hydrogen and N_{CH4} for methane and relate both to each other. One obtains

$$N_{H2} / N_{CH4} = (?_{H2} / ?_{CH4})^{n} \; (?_{CH4} / ?_{H2})^{2} \; (HHV_{CH4} / HHV_{H2})^{3-n} \qquad (6)$$

Since the pumps run continuously, the power ratio also represents the ratio of the energy consumption for pumping.

Because of the low volumetric energy density of hydrogen, the flow velocity must be increased by over three times. Consequently, the flow resistance is increased significantly, but the effect is partially compensated for by the lower viscosity of hydrogen. Still, for the same energy flow about 4.6 times more energy is needed to move hydrogen through the pipeline compared to natural gas. As this energy is taken from the gas stream, more gas is fed into the pipeline than is delivered at the far end of the tube.

Figure 11 shows the results of this approximate analysis. While the energy consumption for methane (representing natural gas) appears reasonable, the energy needed to move hydrogen through pipelines makes this type of hydrogen distributions difficult. Not 0.3% but at least 1.4% of the hydrogen flow is consumed every 150 km to energize the compressors. Only 60 to 70% of the hydrogen fed into a pipeline in Northern Africa would actually arrive in Europe

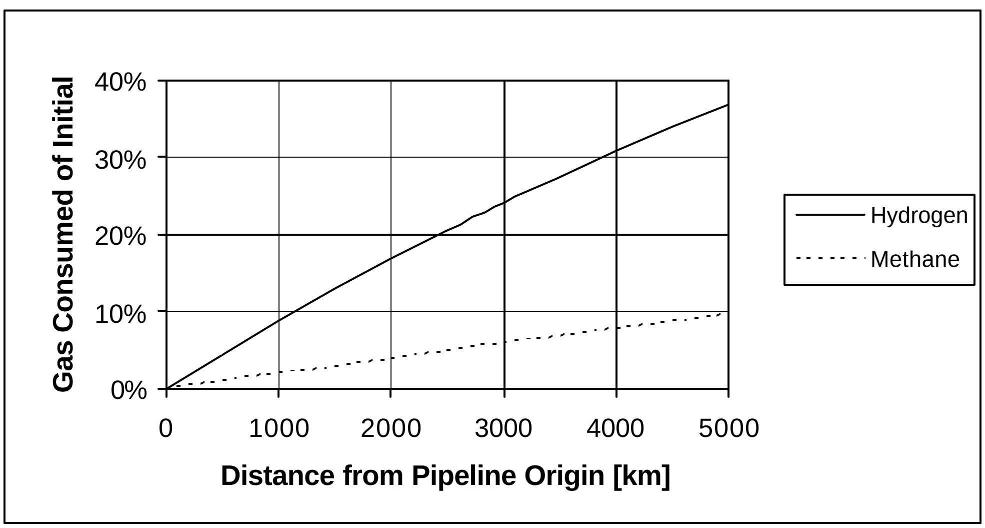

Figure 11 The fraction of the gas consumed to energize the pumps corresponds to the relative energy consumption (ratio of energy needed to HHV energy content) of the transported gases

6.3 Onsite Generation of Hydrogen

One option for providing clean hydrogen at filling stations and dispersed depots is the on-site generation of the gas by electrolysis. Again, the energy needed to generate and compress hydrogen by this scheme is compared to the HHV energy content of the hydrogen delivered to local customers. Natural gas reforming is not considered for reasons stated earlier.

The analysis is done for single gas station serving 100 to 2,000 conventional road vehicles per day. On the average, each car or truck is assumed to accept 60 liters (= 50 kg) of gasoline or diesel. For the 100 and 2000 vehicles per day the energy equivalent would be about 1,700 to 34,000 kg of hydrogen per day, respectively. But on a tank-to-wheel basis fuel cell vehicles consume less energy per driven distance than cars equipped with IC engines. Based on the HHV of both gasoline and hydrogen, we assume that fuel cell vehicles need only 70% of the energy consumed by IC engine vehicles to travel the same distance.

The key assumptions for continuous operation of the onsite hydrogen plant and the most important results are the following:

Vehicles / day	1/d	100	500	1000	1500	2000
Gasoline, Diesel / vehicle	kg	50	50	50	50	50
Fossil energy supplied	GJ/d	241	1,203	2,407	3,610	4,814
Efficiency factor	%	70	70	70	70	70
Hydrogen energy supplied	GJ/d	176	878	1,755	2,633	3,510
Hydrogen mass supplied	kg/d	1,188	5,938	11,877	17,815	23,753
Electrolyzer efficiency	%	70	75	78	79	80
AC/DC conversion	%	93	94	95	96	96
Energy for electrolysis	GJ/d	3259	1,195	2,274	3,332	4,388
Water needed	m^3/d	11	53	107	160	214
Energy for water supply	GJ/d	8	36	68	100	132
H_2-compression, 200 bar	GJ/d	25	109	204	295	384
Total energy needed	GJ/d	292	1,340	2,546	3,727	4,903
Continuous power needed	MW	3	16	29	43	57
Relative to supplied H_2 HHV	%	173	159	151	147	146
Energy wasted per H_2 HHV	%	73	59	51	47	46

The electrolyzer efficiency varies with size from 70 to 80% for 100 and 2,000 vehicles per day, respectively. Also, losses occur in the AC-DC power conversion. Between 3 and 51 MW of power are needed for making hydrogen by electrolysis. Additional power is needed for the water make-up (0.09 to 1.52 MW) and for the compression of the hydrogen to 200 bar (0.29 to 4.45 MW). In all, between 3 and 57 MW of electric power must be supplied to the station to generate hydrogen for 100 to 2,000 vehicles per day.

It may be of interest that between 11 and 214 m^3 of water are consumed daily. The higher number corresponds to about 2.5 liters per second.

The results of this analysis are presented in Figure 12. The total energy needed to generate and compress hydrogen at filling stations exceeds the HHV energy of the delivered hydrogen by 50%. The availability of electricity may certainly be questioned. Today, about one sixth of the energy for end-use is supplied by copper wires. The generation of hydrogen at filling stations would require a 3 to 5 fold increase of the electric power generating capacity. The energy output of a 1 GW nuclear power plant is needed to serve twenty to thirty hydrogen filling stations on frequented highways.

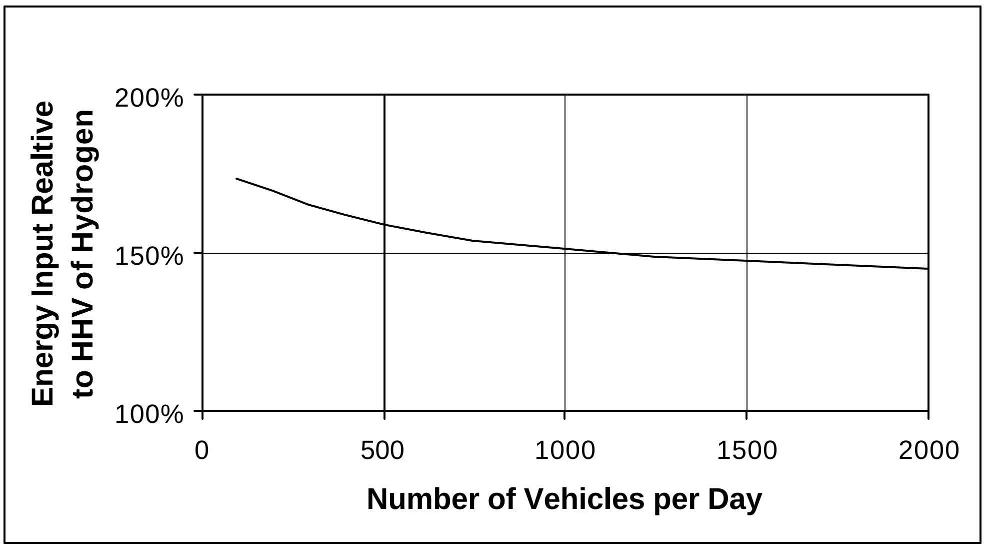

Figure 12 Energy needed for onsite generation of hydrogen by electrolysis and for compression to 200 bars at filling stations compared to the HHV energy content of the hydrogen delivered to road vehicles

7. Transfer of Hydrogen

Liquid can be drained from a full into an empty container by action of gravity. There is no energy required, unless the liquids are transferred from a lower to a higher tank, under controlled flow rates or under accelerated conditions.

The transfer of pressurized gases obeys different laws. Figure 13 may illustrate the point. Assume two tanks of equal volume, one full at 200 bar and the other empty at 0 bar pressure. After opening the valve between the vessels gas will flow into the empty tank, but the flow will cease when pressure equilibration is accomplished. Both tanks are half full or half empty. A pump is required to transfer the remaining content of the supply tank into the receiving tank. The transfer process may be complicated by temperature effects. The content of the full tank is cooled by the expansion process. At equal pressures, the density of the remaining gas is higher than that of the transferred gas in the other tank. As a consequence, more mass remains in the original vessel than is transferred into the empty one. Equal mass transfer is accomplished only after the temperatures have reached equilibrium after some time.

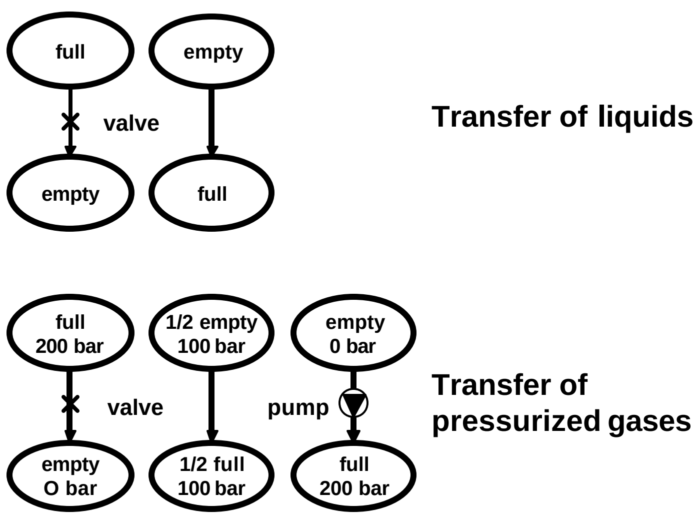

Figure 13 Schematic representation of the transfer of liquids and gases

For the sample case considered, and for an ideal isothermal compression, the amount of energy required to complete the gas transfer by pumping is given by the difference of the total compression energy contained in the gas at the final pressure p_2 and the intermediate pressure p_1. The product p V (= R T) is the same for both compression processes.

$$W = p_0 V_0 \ln(p_2/p_0) - p_0 V_0 \ln(p_1/p_0)$$

with	W	[J/kg]	specific compression work
	p_0	[Pa]	initial pressure
	p_1	[Pa]	intermediate pressure
	p_2	[Pa]	final pressure
	V_0	[m^3/kg]	initial specific volume

For the sample case

p_0	= 1 bar	= 1.0×10^5 Pa
p_1	= 100 bar	= 1.0×10^7 Pa
p_2	= 200 bar	= 2.0×10^7 Pa
V_0	= 11.11 m^3/kg	
p_0V_0	= 1.111 GJ/kg	

one obtains for the energy needed to transfer the remaining hydrogen from the half empty supply tank into the receiving tank by an isothermal compression

$$W = 0.77 \text{ GJ/kg}$$

or about 0.5% of the HHV energy content of the compressed hydrogen. For a more realistic adiabatic compression and including mechanical and electrical losses one would have obtained about 1%.

This number depends on the actual transfer conditions. Much more energy is needed to transfer hydrogen from a large 100 bar tank into a small container at 500 bar pressure. But it takes no additional energy to fill a small tank from a high pressure vessel of substantial size. For automotive application, one aims at high pressure tanks in vehicles and, as a consequence, has to use energy to transfer the hydrogen from large storage containers which cannot be subjected to high internal pressures. In any event, the transfer of hydrogen may add to the energy needs of a hydrogen economy.

8. Summary of Results

The reported results are by no means final. The readers of this study are invited to refine the analysis and to contribute further details. The energy cost of producing, packaging, distributing, storing and transferring hydrogen must have been analyzed in different contexts. The results of those studies may be used to verify, correct, or reject our numbers. Whatever, the intent of this compilation is to create an awareness about the weaknesses of a pure hydrogen economy. We are surprised to discover that, apparently, the energy needed to run a hydrogen economy have never been fully assessed before.

Again, we would like to emphasize that the conversion of natural gas into hydrogen cannot be the solution of the future. Hydrogen produced by natural gas reforming may cost less than hydrogen obtained by electrolysis, but natural gas itself is as good as hydrogen or even better for many applications. For given energy demand the well-to-wheel efficiency is reduced and, as a consequence, the emission of CO_2 is increased when natural gas is converted to hydrogen for daily use. For the final discussion the key results are tabulated below.

	Energy cost in HHV of H_2	Factor	Path A gas	Path B liquid	Path C onsite	Path D hydride
Production of H_2						
Electrolysis	43%	1.43	1.43	1.43		1.22*
Onsite production	65%	1.65			1.65	
Packaging						
Compression 200 bar	8%	1.08	1.08			
Compression 800 bar	13%	1.13				
Liquefaction	40%	1.40		1.40		
Chemical hydrides	60%	1.60				1.60
Distribution						
Road, 200 bar H_2, 100 km	6%	1.06	1.06			
Road, liquid H_2, 100 km	1%	1.01		1.01		
Pipeline, 1,000 km	10%	1.10				
Storage						
Liquid H_2, 10 days	guess: 5%	1.05		1.05		
Transfer						
200 bar to 200 bar	1%	1.01	1.01		1.01	
Delivered to User						
Energy Input to HHV of H_2			1.65	2.12	1.66	1.95

* Only 50% of the liberated hydrogen comes from electrolysis

Four typical energy paths have been considered to interpret the results. These are:

A Hydrogen is produced by electrolysis, compressed to 200 bar and distributed by road to filling stations or consumers

B Hydrogen is produced by electrolysis, liquefied and distributed by road to filling stations or consumers

C Hydrogen is produced onsite at filling stations or consumers

D Hydrogen is produced by electrolysis and used to make alkali metal hydrides.

The analysis for ideal processes reveals that considerable amounts of energy are lost between the electrical source energy and the HHV hydrogen energy delivered to the consumer. For onsite hydrogen production, path C, the electrical energy input exceeds the HHV energy of the delivered hydrogen by a factor of at least 1.65. In the case of liquid hydrogen, path B, the factor is at lest 2.12. For all stationary applications the distribution of energy by copper wire will be a better choice than the use of hydrogen as energy carrier.

But the problems of road delivery of compressed hydrogen have been discussed. It is unlikely that Path A can be realized. A better option would be the hydrogen distribution by short pipelines. To deliver hydrogen by chemical hydrides may provide practical solutions in some niche markets, but path D cannot become an important energy vector in a future economy.

Today, about 12% of the original fossil energy is lost between oil wells and filling stations for transportation, refining and distribution. In a pure hydrogen economy the losses would be considerably higher. If hydrogen could be chemically packaged in a synthetic liquid fuel, the overall energy consumption would be considerably lower.

8.1 The Limits of a Pure Hydrogen Economy

The results of this analysis indicate the weakness of a "Pure-Hydrogen-Only-Economy" as depicted in Figure 14. Hydrogen is not only obtained by electrolysis, but also by chemical conversion of biomass. The economy is based on the natural H_2O cycle, but the natural CO_2-cycle is truncated and not fully used.

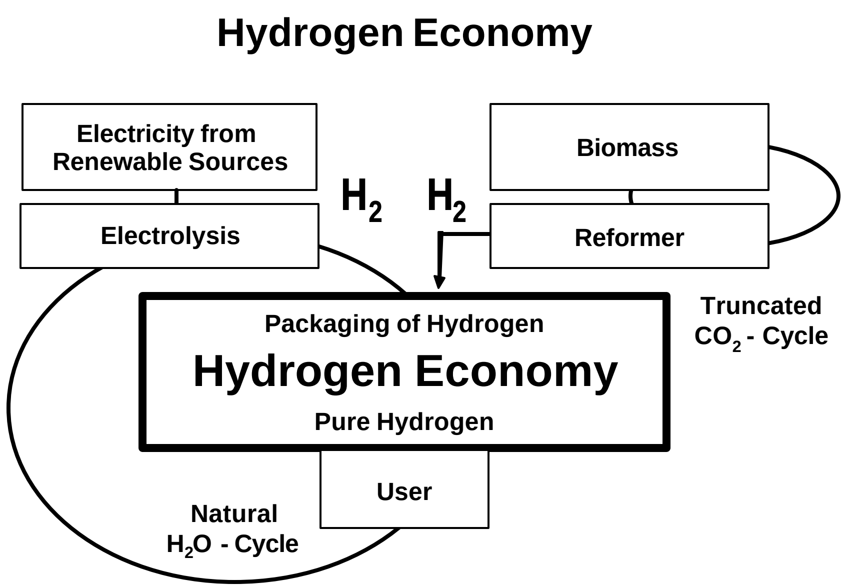

Figure 14 Pure Hydrogen Economy based on the natural cycle of water. Pure hydrogen is provided to the user

All difficulties with the pure Hydrogen Economy appear to be directly related to the nature of hydrogen. Most of the problems cannot be solved by additional research and development. We have to accept that hydrogen is the lightest of all gases and, as a consequence, that its physical properties do not fully match the requirements of the energy market. Production, packaging, storage, transfer and delivery of the gas, in essence all key component of an economy, are so energy consuming that alternatives should and will be considered. Mankind cannot afford to waste energy for idealistic goals, but economy will look for practical solutions and select the most energy-saving procedures. The "Pure-Hydrogen-Only-Solution" may never become reality.

The degree of energy waste certainly depends on the chosen path. Hydrogen generated from rooftop solar electricity and stored at low pressure in stationary tanks may be a viable solution for private buildings. On the other hand, hydrogen generated in the Sahara desert, pumped to the Mediterranean Sea through pipelines, then liquefied for sea transport, docked in London and locally distributed by trucks may not provide an acceptable energy solution at all. Too much energy is lost in the process to justify the scheme. But there are solutions between these two extremes, niche applications, special cases or luxury installations. This study provides some clues for strengths and weaknesses of the energy carrier hydrogen.

As stated in the beginning, hydrogen may be the only link between physical energy from renewable sources and chemical energy. It is also the ideal fuel for modern clean energy conversion devices like fuel cells or even hydrogen engines. But hydrogen is not the ideal medium to carry energy from primary sources to distant end users. New solutions must be considered for the commercial bridge between electrolyzer and fuel cell.

8.2 A Liquid Hydrocarbon Economy

The ideal energy carrier is a liquid with a boiling point above 80°C and a solidification point below -40°C. Such energy carriers stay liquid under normal climate conditions and at high altitudes. Gasoline, diesel and methanol are good examples of such fuels. They are in common use not only because they can be extracted from crude oil, but mainly, because they qualify for widespread use because of their physical properties.

Oil companies convert crude oil into gasoline and diesel fuels. Even if oil had never been discovered, the world would not use synthetic hydrogen, but one or more synthetic hydrocarbon fuel. Gasoline, diesel, heating oil etc. have emerged as the best solutions with respect to handling, storage, transport and energetic use. With high certainty, such liquids will also be synthesized from hydrogen and carbon in a distant energy future. Fortunately, methanol and ethanol can also be derived from plants by biological fermentation processes.

There are a number of synthetic hydrocarbons to be considered. One of the prime choices may be methanol. It carries four hydrogen atoms per carbon atom. It is liquid under normal conditions. The infrastructure for liquid fuels exists. Also, methanol can either be directly converted to electricity by Direct Methanol Fuel Cells (DMFC), Molten Carbonate Fuel Cells (MCFC) and Solid Oxide Fuel Cells (SOFC). It can also be reformed easily to hydrogen for use in Polymer Electrolyte Fuel Cells (PEFC or PEM). Methanol could become a universal fuel for fuel cells and many other applications.

Liquid Hydrocarbon Economy

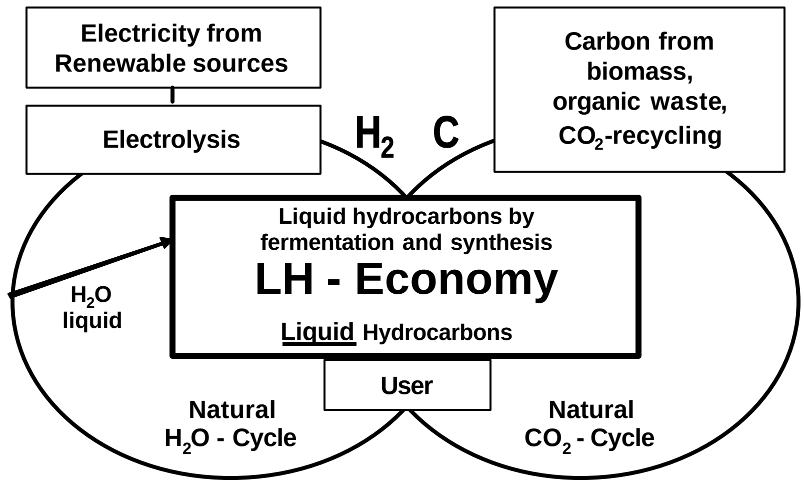

Figure 15 A Liquid Hydrogen Economy is based on the two natural cycles of water and carbon dioxide. Natural and synthetic liquid hydrocarbons are provided to the user

Figure 15 shows a schematic of a "Liquid Hydrocarbon Economy" (in short: "LH Economy"). It is based on the two natural cycles of water and carbon dioxide. Carbon from the biosphere may become the key element in a sustainable energy future. It could come from biomass, from organic waste and from captured CO_2. Typically, biomass has a hydrogen-to-carbon ratio of two. In the methanol synthesis two additional hydrogen atoms are attached to every bio-carbon. Instead of converting biomass into hydrogen, hydrogen from renewable sources or even water could be added to biomass to form methanol by a chemical process. In a LH economy carbon atoms will stay bound in the energy carrier until its final use. They are then returned to the atmosphere (or recycled). This is true not only for methanol, but also for ethanol or other synthetic hydrocarbons. The suggested scheme should be seriously considered for the planning of a clean and sustainable energy future.

8.3 Liquid Hydrocarbons

Any synthetic liquid fuel must satisfy a number of requirements. It should be liquid under normal pressure at temperatures between -40°C and 80°C, be nontoxic, be useful for IC engines, easy to synthesize etc. The chemicals tabulated below satisfy the liquidity criteria. They may serve to illustrate that a number of options exist for the synthesis of liquid hydrocarbons from hydrogen and carbon. But aspects of manufacturing, safety, combustion etc., all well-known to the experts, will eliminate some or add new options to the list.

The following liquid hydrocarbons are considered:

A	Methanol	CH_4O	or CH_3OH
B	Ethanol	C_2H_6O	or CH_3CH_2OH
C	Dimethlyether (DME)	C_2H_6O	or CH_3OCH_3
D	Ethylmethylether	$C_4H_{10}O$	or $CH_3OC_2H_5$
E	2-Methylpropane (Isubutane)	C_4H_{10}	or $CH_3CH(CH_3)CH_3$
F	2-Methylbutane (Isopentane)	C_5H_{12}	or $CH_3CH(CH_3)CH_2CH_3$
G	Ethylbenzol	C_8H_{10}	or $C_6H_5CH_2CH_3$
H	Methylcyclohexane (Toluol)	C_7H_{14}	or $C_6H_5CH_3$
I	Octane	C_8H_{18}	or $CH_3(CH_2)_3CH_3$
J	Ammonia	NH_3	
K	Hydrogen (for comparison)	H_2	

Methanol, Ethanol, DME, Toluol and Ammonia, all having relatively simple molecular structures, may become the preferred synthetic energy carriers of the future in competition with liquid (or 800 bar) hydrogen. The ten substances are characterized by the following technical numbers:

Fuel	Mol. Weight	Density	H_2-Content	H_2-Density	HHV	Energy per Volume
	mole	kg/m^3	$moleH_2/mole$	kgH_2/m^3	MJ/kg	GJ/m^3
A	32	792	0.125	99	22.7	17.97
B	46	789	0.130	103	29.7	23.45
C	46	666	0.130	87	31.7	21.14
D	74	714	0.135	96	28.5	20.34
E	58	557	0.172	96	49.4	27.54
F	72	620	0.167	103	48.7	30.17
G	106	866	0.094	82	43.1	37.30
H	112	769	0.125	96	34.9	26.85
I	114	703	0.158	111	48.0	33.73
J	17	770	0.176	136	22.5	17.35
K	2	70	1.000	70	141.9	9.93

The results are depicted in Figure 16. Any one of the nine hydrocarbon fuels contains more hydrogen per cubic meter than is contained in the same volume of liquefied or 800 bar compressed hydrogen. Ammonia even contains even 136 kg of hydrogen per cubic meter. Also, the energy carried by the hydrocarbons is between two and almost four times greater than the energy contained in the same volume of liquid hydrogen. If one wants to distribute hydrogen, obviously the best way is combining it with carbon to a liquid fuel. It may be of interest to observe that the gasoline-like Octane seems to be the best hydrogen carrier and also ranks among the best with respect to energy content per volume. The synthesis of Octane from bio-carbon and water may pose an attractive solution for an energy economy based on renewable energy sources and the recycling of carbon dioxide.

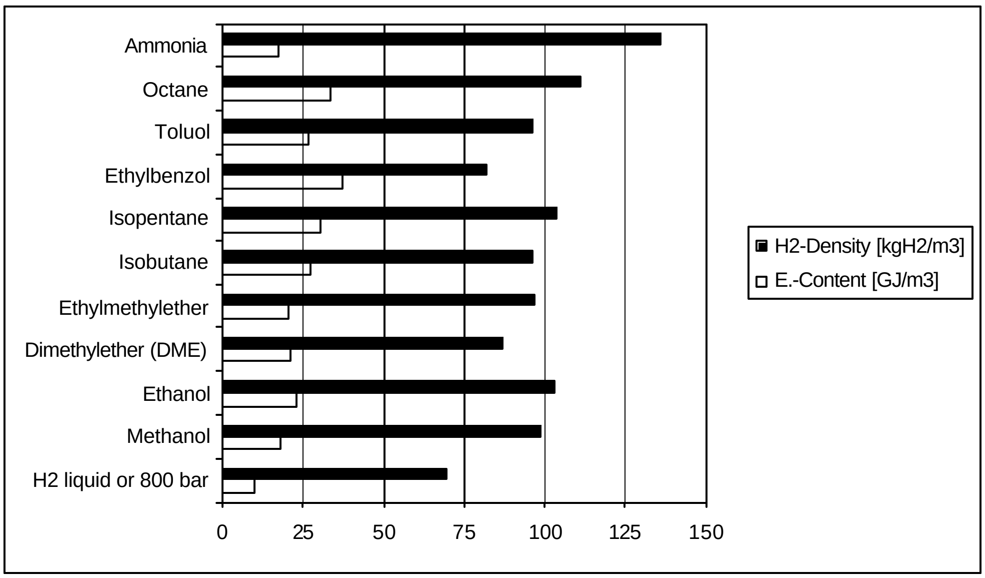

Figure 16 Hydrogen density and HHV energy content of selected synthetic liquid hydrocarbon fuels and Ammonia

9. Conclusions

Time has come to shift the attention of energy strategy planning, research and development from a “Hydrogen Economy” to a “Synthetic Liquid Hydrocarbon Economy” and to direct manpower and resources to find technical solutions for a sustainable energy future which is built on the two closed clean natural cycles of water and CO_2 or hydrogen and carbon. If carbon is taken from the biosphere or recycled from power plants ("bio-carbon") and not from fossil resources ("geo-carbon"), the "Synthetic Liquid Hydrocarbon Economy" will be environmentally as benign as a "Pure Hydrogen Economy".

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About the Authors

Ulf Bossel

Born 1936 in Germany, studied Mechanical Engineering in Darmstadt (Germany) and the Swiss Federal Institute of Technology in Zurich, where he received his Diploma Degree (fluid mechanics, thermodynamics) in 1961. After a short work period at BBC, he continued his graduate education at the University of California at Berkeley. He received his Ph.D. degree in 1968 for experimental research in the area of space aerodynamics. After two years as Assistant Professor at Syracuse University he returned to Germany to lead the free molecular flow research group at the DLR in Göttingen. He left the field for solar energy in 1976, was founder and first president of the German Solar Energy Society, and started his own R&D consulting firm for renewable energy technologies. In 1986 BBC asked him to join their new technology group in Switzerland. He became involved in fuel cells in 1987 and later director of ABB's fuel cell development efforts worldwide. After ABB's decided to concentrate its resources on the development of more conventional energy technologies, he established himself as a free-lancing fuel cell consultant with clients in Europe, Japan and the US. He has created and is still in charge of the annual fuel cell conference series of the European Fuel Cell Forum in Lucerne.

Baldur Eliasson

Born1937 in Iceland, studied Electrical Engineering and Astronomy at the Swiss Federal Institute of Technology in Zurich, where he received his doctorate in 1966 on a theoretical study of microwave propagation. He then worked for three years as radio astronomer at the California Institute of Technology at Pasadena before joining the newly founded Brown Boveri (later ABB) Research Center in Switzerland in 1969. He is in charge of ABB's Energy and Global Change Program worldwide and reports directly to ABB's Chief Technology Officer. He represents ABB in a number of international programs. For instance, he is Vice Chairman of the "R&D Program on Greenhouse Gas Mitigation Technologies" of the International Energy Agency. He has received many international awards for his contributions to environmental sustainability.

https://www.eia.gov/energyexplained/hydrogen/#:~:text=Hydrogen%20is%20an%20energy%20carrier&text=Hydrogen%2C%20like%20electricity%2C%20is%20an,source%20of%20energy%20or%20fuel.

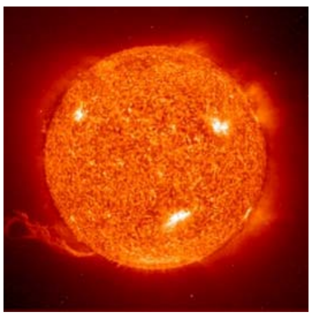
eia Independent Statistics & Analysis U.S. Energy Information Administration

Hydrogen explained

What is hydrogen?

Hydrogen is the simplest element. Each atom of hydrogen has only one proton. Hydrogen is also the most abundant element in the universe. Stars such as the sun consist mostly of hydrogen. The sun is essentially a giant ball of hydrogen and helium gases.

Hydrogen occurs naturally on earth only in compound form with other elements in liquids, gases, or solids. Hydrogen combined with oxygen is water (H_2O). Hydrogen combined with carbon forms different compounds—or hydrocarbons—found in natural gas, coal, and petroleum.



The sun is essentially a giant ball of hydrogen gas undergoing fusion into helium gas. This process causes the sun to produce vast amounts of energy.

Source: NASA (public domain)
?

Hydrogen is the lightest element. Hydrogen is a gas at normal temperature and pressure, but hydrogen condenses to a liquid at minus 423 degrees Fahrenheit (minus 253 degrees Celsius).

Hydrogen is an energy carrier

Energy carriers allow the transport of energy in a usable form from one place to another. Hydrogen, like electricity, is an energy carrier that must be produced from another substance. Hydrogen can be produced—separated—from a variety of sources including water, fossil fuels, or biomass and used as a source of energy or fuel. Hydrogen has the highest energy content of any common fuel by weight (about three times more than gasoline), but it has the lowest energy content by volume (about four times less than gasoline).

It takes more energy to produce hydrogen (by separating it from other elements in molecules) than hydrogen provides when it is converted to useful energy. However, hydrogen is useful as an energy source/fuel because it has a high energy content per unit of weight, which is why it is used as a rocket fuel and in fuel cells to produce electricity on some spacecraft. Hydrogen is not widely used as a fuel now, but it has the potential for greater use in the future.

Last updated: January 20, 2022

Dan Tsubouchi @Energy_Tidbits · 1h

Big China EV/Hybrid sales in Q1 but still a long way to go to catch up to ICE.

NEV = EV + PHEV + HEV

Mar: Total 1.7 mm. NEV 0.70 mm. ICE 1.0 mm.
Q1/24: Total 4.84 mm. NEV 1.76 mm. ICE 3.08mm.

Fits 👇 03/30 tweet thesis.

#OOTT

https://english.news.cn/20240404/6439fed9c23d4f8ea64e57a71f9cd7f02/c.html

China's passenger vehicle sales up 7 pct in March

Source: Xinhua
Editor: huaxia
2024-04-04 10:59:00

BEIJING, April 4 (Xinhua) -- China's passenger vehicle sales stood at 1.7 million units in March, up 7 percent year on year, or 54 percent month on month, industry data showed.

In the first three months of this year, passenger vehicle sales totaled 4.84 million units, surging 13 percent year on year, according to the latest data from the China Passenger Car Association.

During the period, China's new energy vehicle (NEVs) sales rose 34 percent year on year to 1.76 million units.

In March alone, the country's NEV sales reached 698,000 units, up 28 percent year on year, or 80 percent month on month, the association added.

> **Dan Tsubouchi** @Energy_Tidbits · Mar 30
>
> it's a yr ago, but @BloombergNEF reminds in 👇 04/26/23 tweet why EVs don't displace #Oil as fast as aspirations.
>
> China has big EV adds BUT also has big NET ICE adds.
>
> ...

1 · 4 · 1.6K

Dan Tsubouchi @Energy_Tidbits · 2h

Breaking!

Will #Oil market see this as Iran taking direct military attack vs Israel off the table for now? ie. less price tension.

Iran media "*No Israeli embassy is safe anymore; resistance ready to strike: Top Iran general*"

Yes an attack on embassies/consulates is still an...
Show more

https://www.presstv.ir/Detail/2024/04/07/723239/Iran-general-Rahim-Safavi-Israel-embassy

No Israeli embassy is safe anymore; resistance ready to strike: Top Iran general

Sunday, 07 April 2024 10:51 AM [Last Update: Sunday, 07 April 2024 10:53 AM]

Major General Yahya Rahim Safavi, a top military adviser to Leader of the Islamic Revolution Ayatollah Seyyed Ali Khamenei (Photo by Tasnim news agency)

None of the embassies of the Israeli regime are safe anymore, a top military adviser to the Leader of the Islamic Revolution Ayatollah Seyyed Ali Khamenei has warned.

In remarks on Sunday, Major General Yahya Rahim Safavi said the Leader promised a slap on the face of the Israeli regime such that the regime will regret attacking Iran's consulate in Syria, adding that the Resistance Front is fully prepared to deliver on that promise.

"We have to wait and see what will happen," the general said.

"None of the Zionist regime's embassies are safe anymore, and therefore, it has so far closed down 28 of its embassies out of fear," he added.

Rahim Safavi, a former chief commander of the Islamic Revolution Guards Corps, further said that Israeli settlers are living in fear due to the reckless attack on Iran's consulate.

"They dream of dying every night and they are the most fearful creatures," he stated.

Leader of the Islamic Revolution Ayatollah Seyyed Ali Khamenei says brave Iranian men will "punish" Israel and make the evil regime "regret" its crime of assassinating military advisors in Syria.

On Monday afternoon, Israeli warplanes bombed the consular annex of Iran's embassy in the Syrian capital of Damascus.

The air raid killed 13 people, including seven members of the Islamic Revolution Guards Corps (IRGC) who were on an advisory mission to Syria.

Iranian officials have emphasized the country's right to deliver a firm response to the Israeli crime that violated all international obligations and conventions.

Press TV's website can also be accessed at the following alternate addresses:

www.presstv.co.uk

1 · 1 · 8 · 1.5K

Dan Tsubouchi @Energy_Tidbits · 16h

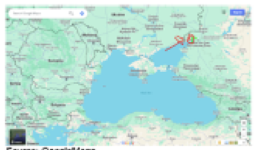
Was this a Ukraine warning shot they can do more damage to RUS export capability if they want?

See 👇 03/27 @CroftHelima potential risk

Bombs pipeline taking products from fuel depot to likely small tankers

But could have gone after major Black Sea export infra?

#OOTT



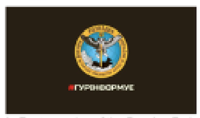
Source: GoogleMaps

https://en.interfax.com.ua/news/general/978535.html

12:34 06.04.2024

Pipeline for pumping petroleum products blown up in Rostov region in Russia – Defense Intelligence

1 min read



In Rostov region of the Russian Federation, a pipeline used to pump petroleum products from a local oil depot to tankers in the area of the Azov Sea Port was blown up, the Defense Intelligence of the Ministry of Defense of Ukraine reported on Telegram.

"On the night of April 6, 2024, in the area of the village of Azov (Rostov region) as a result of the explosion of a pipeline that pumped petroleum products from a local oil depot to tankers in the area of the Azov Sea Port, the loading of tankers with petroleum products was suspended for an indefinite period," the report says.

"The object was used by the aggressor state for military purposes, to support the waging of a genocidal war against Ukraine," the department noted.

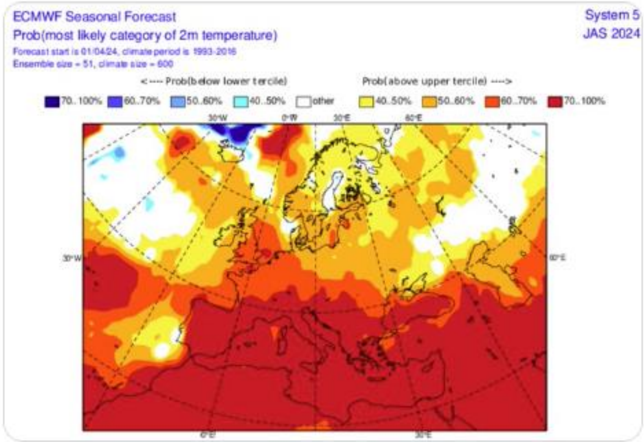
> **Dan Tsubouchi** @Energy_Tidbits · Mar 31
>
> This 👇 Must Read from @CroftHelima looks even more relevant with the last 4 days, incl last night, of escalating Russia drone attacks on Ukraine energy/power infra.
>
> Will Ukraine expand its drone attacks to target RUS oil export facilities...

3 · 6 · 12 · 4K

Dan Tsubouchi @Energy_Tidbits · 18h

Won't really move TTF #NatGas prices for now but @ECMWF forecasts another warm summer (Jul/Aug/Sep) in Europe.

#OOTT



1 · 2 · 5 · 2.2K

Dan Tsubouchi @Energy_Tidbits · Apr 6

#Oil floating storage 67.19 mmb Apr 5

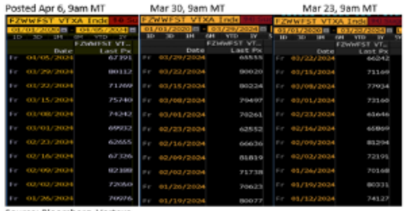
Big revision up in Mar 29 but prior 3 wks revised down.

Last 7 wks ave 71.7 mmb ie. floating normalizing at lower levels as refiners/tankers have worked in longer trips and OPEC keeps cuts thru Q2

Thx @vortexa @business #OOTT

Vortexa Crude Oil Floating Storage Estimate Jan 1, 2020 – Apr 5, 2024, Posted as of 9am MT, Apr 6

Source: Bloomberg, Vortexa



Posted Apr 6, 9am MT Date	Last Px	Mar 30, 9am MT Date	Last Px	Mar 23, 9am MT Date	Last Px
Fr 04/05/2024	67191	Fr 03/29/2024	65555	Fr 03/22/2024	66242
Fr 03/29/2024	80112	Fr 03/22/2024	80020	Fr 03/15/2024	71169
Fr 03/22/2024	71269	Fr 03/15/2024	80224	Fr 03/08/2024	77934
Fr 03/15/2024	75740	Fr 03/08/2024	79497	Fr 03/01/2024	73160
Fr 03/08/2024	74242	Fr 03/01/2024	70261	Fr 02/23/2024	61646
Fr 03/01/2024	69932	Fr 02/23/2024	62552	Fr 02/16/2024	65869
Fr 02/23/2024	62655	Fr 02/16/2024	66636	Fr 02/09/2024	81294
Fr 02/16/2024	67326	Fr 02/09/2024	81819	Fr 02/02/2024	72191
Fr 02/09/2024	82388	Fr 02/02/2024	71738	Fr 01/26/2024	70168
Fr 02/02/2024	72050	Fr 01/26/2024	70623	Fr 01/19/2024	80331
Fr 01/26/2024	70976	Fr 01/19/2024	80077	Fr 01/12/2024	74127

Source: Bloomberg, Vortexa

Vortexa Crude Oil Floating Storage by Region (mmb)				Original Posted	Recent Peak	
Region	Apr 5/24	Mar 29/24	WoW	Mar 29/24	Jun 23/23	Apr 5 vs Jun 23
Asia	30.07	41.62	-11.55	31.54	73.01	-42.94
Europe	12.33	11.68	0.65	9.68	6.21	6.12
Middle East	7.48	5.11	2.37	7.48	6.76	0.72
West Africa	7.33	4.95	2.38	5.94	7.62	-0.29
US Gulf Coast	0.92	1.93	-1.01	2.48	1.00	-0.08
Other	9.06	14.82	-5.76	8.49	35.51	-26.45
Global Total	67.19	80.11	-12.92	65.56	130.11	-62.92
Vortexa crude oil floating storage posted on Bloomberg 9am MT on Apr 6						
Source: Vortexa, Bloomberg						

Prepared by SAF Group: https://safgroup.ca/news-insights/

2 · 8 · 17 · 2.9K

Dan Tsubouchi @Energy_Tidbits · Apr 6

US gasoline prices creeping higher.

California gas prices hit $5 last week, +$0.24 WoW to hit $5.32 today.

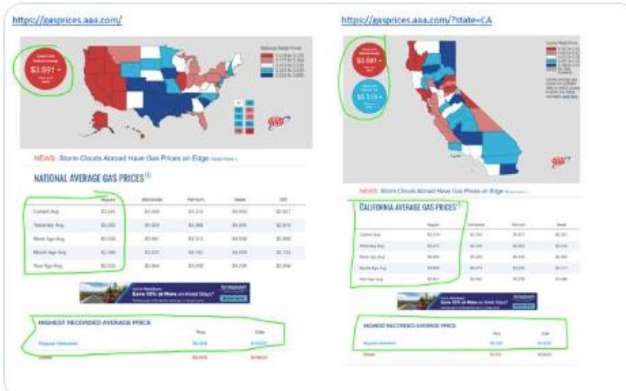
US gas prices +0.05 WoW to $3.59

Gas prices normally seasonally increase into June.

Biden doesn't want $4 gas in election year.

...

Show more



7 13 1.7K

Dan Tsubouchi @Energy_Tidbits · Apr 6

Positive indicator for China.

Net monthly foreign direct investment +5.33b in Feb and +$3.89b in Jan.

Reversed negative flows in four or five prior mths in H2/23.

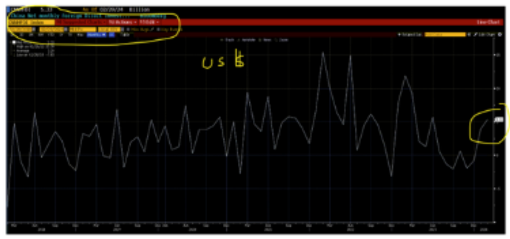
Still a way to go but positive.

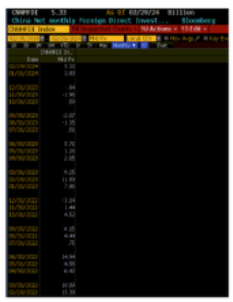
Thx @business

...

Show more

China Net Monthly Foreign Direct Investment from Bloomberg





5 · 8 · 2.9K

Dan Tsubouchi @Energy_Tidbits · Apr 5

321 crack spreads still high.

WTI +$3.74 WoW to close $86.91.

321 crack spreads were -$0.28 WoW to $29.45, BUT crack spreads near $30 still provide big margins for refineries ie, big incentive to maximize runs & buying crude & support for WTI.

#OOTT #Oil Thx @business

Figure 19: Cushing Oil 321 Crack Spread & WTI Apr 5, 2014 to Apr 5, 2024

Source: Bloomberg

Prepared by SAF Group https://safgroup.ca/news-insights/

9 · 37 · 4.9K

Dan Tsubouchi @Energy_Tidbits · Apr 5

Higher US gasoline prices = less $$ for other household consumption

"If you have oil prices continue to move higher, that could pinch consumer spending. Household consumption rolls over, ***that's 70% of GDP,*** *GDP forecasts roll over ...."* @CameronDawson to @lisaabramowicz1...
Show more

3 · 1.3K

Dan Tsubouchi @Energy_Tidbits · Apr 5

typo

meant to write Israel shares the view.

> **Dan Tsubouchi** @Energy_Tidbits · Apr 5
>
> #Oil Watch!
>
> When and what will Iran do?
>
> 👇 CNN @mj_lee ""*US is on high alert and actively preparing for a ...*
> Show more

1.6K

Dan Tsubouchi @Energy_Tidbits · Apr 5

#Oil Watch!

When and what will Iran do?

👇 CNN @mj_lee ""*US is on high alert and actively preparing for a "significant" attack within the next week by Iran targeting Israeli or American assets in the region*"

US believes an attack is "*inevitable*", Iran shares that view.
#OOTT

> **MJ Lee** @mj_lee · Apr 5
>
> New: The US is on high alert and actively preparing for a "significant" attack by Iran that could come as soon as within the next week targeting Israeli or American assets in the region, a senior administration official tells CNN.
> cnn.com/2024/04/05/pol...

1 · 3 · 15 · 5.6K

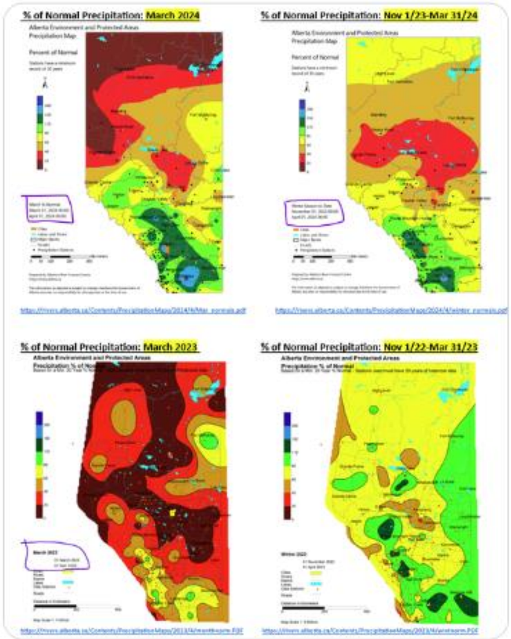
Dan Tsubouchi @Energy_Tidbits · 1h

Bad setup for 2024 wildfire season in Alberta.

Nov 1/23 thru Mar 31/24 precipitation is <60% of norm for half of Alberta incl a sizeable portion <40% of norm.

Also could impact water access for oil & gas.

#OOTT



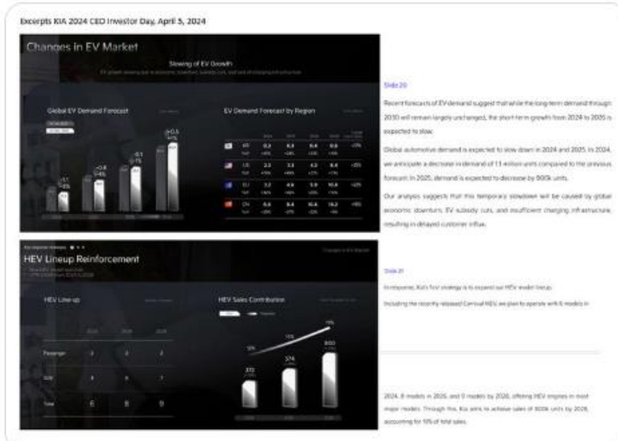
2 833

Dan Tsubouchi @Energy_Tidbits · 5h

KIA cuts **Global** EV demand forecast for 24/25.

2024 revised -1.1 mm to 13.5 mm (was 14.6)
2025 revised -0.8 mm to 18.4 mm (was 19.2)
Back to prior in 2026
2030 revised +0.5 mm to 40.9 mm (was 40.4)

How can IEA not lower its fcast EVs displace ~5.5 mmb/d of oil by 2030?
#OOTT



1 3 1.2K

Dan Tsubouchi @Energy_Tidbits · 5h

Oil Bulls will like these charts.

"Oil's Under-the-Hood Signals Tell Tale of Very Bullish Market" by
@business @yongchang_chin @Devikakrishnak @alexlongley1

#OOTT

3 9 1.2K

Dan Tsubouchi @Energy_Tidbits · 13h

Port of Baltimore update.

Expects to open a limited access channel 280 ft wide and 35 ft deep by end of Apr.

"*aiming to reopen the permanent, 700-ft-wide by 50-ft-deep federal navigation channel by the end of May, restoring port access to normal capacity.*"
#OOTT #Coal

https://content.govdelivery.com/accounts/MDMPA/bulletins/394767a

Timeline From Army Corps On Reopening Channel

MDOT Maryland Port Administration sent this bulletin at 04/04/2024 06:26 PM EDT

Port of Baltimore
Generating Jobs for Maryland
Brought to you by the Maryland Department of Transportation Maryland Port Administration

April 4, 2024

Dear Subscriber,

BALTIMORE – As the U.S. Army Corps of Engineers (USACE), Baltimore District continues working with local, state and federal partners to clear the wreckage along the Fort McHenry Channel following the collapse of the Francis Scott Key Bridge, engineers have determined a tentative timeline for the restoration for safe navigation in and out of the Port of Baltimore.

After detailed studies and engineering assessments by local, state and federal organizations, in collaboration with industry partners, USACE expects to open a limited access channel 280 feet wide and 35 feet deep, to the Port of Baltimore within the next four weeks – by the end of April. This channel would support one-way traffic in and out of the Port of Baltimore for barge container service and some roll on/roll off vessels that move automobiles and farm equipment to and from the port.

USACE engineers are aiming to reopen the permanent, 700-foot-wide by 50-foot-deep federal navigation channel by the end of May, restoring port access to normal capacity.

"Thanks to the exhaustive work of the Unified Command during the last two weeks, including underwater surveys and detailed structural analysis of the wreckage, we've developed a better understanding of the immense and complex work that lies ahead," said Lt. Gen. Scott A. Spellmon, USACE commanding general. "A fully opened federal channel remains our primary goal, and we will carry out this work with care and precision, with safety as our chief priority."

"These are ambitious timelines that may still be impacted by significant adverse weather conditions or changes in the complexity of the wreckage," Spellmon added. "We are working quickly and safely to clear the channel and restore full service at this port that is so vital to the nation. At the same time, we continue to keep faith with the families of the missing and are working with our partners to help locate and recover their loved ones."

2 · 6 · 1.8K

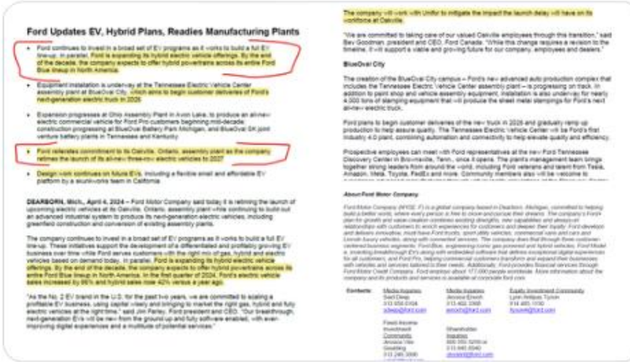
Dan Tsubouchi @Energy_Tidbits · 20h

Will large EVs fade away before they take off?

Today, Ford delays launch of big E-SUVs from 2025 to 2027 due to demand.

👎 03/29 tweet, Ford CFO "***we're going to have some large EVs as well, but they're going to be very limited in the scope and the number***".

#OOTT



Ford Updates EV, Hybrid Plans, Readies Manufacturing Plants

- Ford continues to invest in a broad set of EV programs as it works to build a full EV line-up. In parallel, Ford is expanding its hybrid electric vehicle offerings. By the end of the decade, the company expects to offer hybrid powertrains across its entire Ford Blue lineup in North America.
- Equipment installation is underway at the Tennessee Electric Vehicle Center assembly plant at BlueOval City, which aims to begin customer deliveries of Ford's next-generation electric truck in 2026.
- Expansion progresses at Ohio Assembly Plant in Avon Lake, to produce an all-new electric commercial vehicle for Ford Pro customers beginning mid-decade; construction progressing at BlueOval Battery Park Michigan, and BlueOval SK joint venture battery plants in Tennessee and Kentucky.
- Ford reiterates commitment to its Oakville, Ontario, assembly plant as the company retimes the launch of its all-new three-row electric vehicles to 2027.
- Design work continues on future EVs, including a flexible small and affordable EV platform by a skunkworks team in California.

DEARBORN, Mich., April 4, 2024 – Ford Motor Company said today it is retiming the launch of upcoming electric vehicles at its Oakville, Ontario, assembly plant while continuing to build out an advanced industrial system to produce its next-generation electric vehicles, including greenfield construction and conversion of existing assembly plants.

The company continues to invest in a broad set of EV programs as it works to build a full EV line-up. These initiatives support the development of a differentiated and profitably growing EV business over time while Ford serves customers with the right mix of gas, hybrid and electric vehicles based on demand today. In parallel, Ford is expanding its hybrid electric vehicle offerings. By the end of the decade, the company expects to offer hybrid powertrains across its entire Ford Blue lineup in North America. In the first quarter of 2024, Ford's electric vehicle sales increased by 86% and hybrid sales rose 42% versus a year ago.

"As the No. 2 EV brand in the U.S. for the past two years, we are committed to scaling a profitable EV business, using capital wisely and bringing to market the right gas, hybrid and fully electric vehicles at the right time," said Jim Farley, Ford president and CEO. "Our breakthrough, next-generation EVs will be new from the ground up and fully software enabled, with ever-improving digital experiences and a multitude of potential services."

The company will work with Unifor to mitigate the impact the launch delay will have on its workforce at Oakville.

"We are committed to taking care of our valued Oakville employees through this transition," said Bev Goodman, president and CEO, Ford Canada. "While this change requires a revision to the timeline, it will support a viable and growing future for our company, employees and dealers."

BlueOval City

The creation of the BlueOval City campus – Ford's new advanced auto production complex that includes the Tennessee Electric Vehicle Center assembly plant – is progressing on track. In addition to paint shop and vehicle assembly equipment, installation is also underway for nearly 4,000 tons of stamping equipment that will produce the sheet metal stampings for Ford's next all-new electric truck.

Ford plans to begin customer deliveries of the new truck in 2026 and gradually ramp up production to help assure quality. The Tennessee Electric Vehicle Center will be Ford's first Industry 4.0 plant, combining automation and connectivity to help elevate quality and efficiency.

Prospective employees can meet with Ford representatives at the new Ford Tennessee Discovery Center in Brownsville, Tenn., once it opens. The plant's management team brings together strong leaders from around the world, including Ford veterans and talent from Tesla, Amazon, Meta, Toyota, FedEx and more. Community members also will be welcome to

About Ford Motor Company

Dan Tsubouchi @Energy_Tidbits · Mar 29

Will large EVs fade away before they take off?

No surprise, Ford CFO "*Growth is much less than what we thought*" "*moving into the early majority. & the early majority is much less forgiving, & pricing is an issue*"...

1 · 5 · 10 · 4.9K

SAF Dan Tsubouchi @Energy_Tidbits · 23h

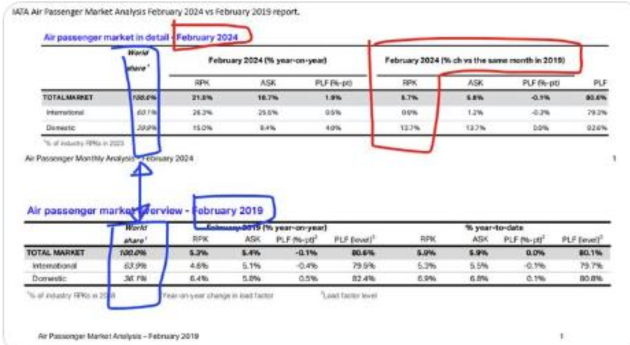
Positive for #Oil

Look for more to follow @vitolnews Gallagher's 👇 03/21 call that jet fuel consumption back to 2019.

@IATA Feb passenger data, both international & domestic are above 2019.

Plus greater share of less fuel efficient domestic volume.

#OOTT



IATA Air Passenger Market Analysis February 2024 vs February 2019 report.

Air passenger market in detail - February 2024

	World share[1]	February 2024 (% year-on-year)			February 2024 (% ch vs the same month in 2019)			
		RPK	ASK	PLF (%-pt)	RPK	ASK	PLF (%-pt)	PLF
TOTAL MARKET	100.0%	21.5%	16.7%	1.9%	5.7%	5.8%	-0.1%	80.6%
International	60.1%	26.2%	25.6%	0.5%	0.9%	1.2%	-0.3%	79.3%
Domestic	39.9%	15.0%	8.4%	4.0%	13.7%	13.7%	0.0%	82.6%

[1]% of industry RPKs in 2023

Air Passenger Monthly Analysis – February 2024 1

Air passenger market overview - February 2019

	World share[1]	February 2019 (% year-on-year)				% year-to-date			
		RPK	ASK	PLF (%-pt)[2]	PLF (level)[3]	RPK	ASK	PLF (%-pt)[2]	PLF (level)[3]
TOTAL MARKET	100.0%	5.3%	5.4%	-0.1%	80.6%	5.9%	5.9%	0.0%	80.1%
International	63.9%	4.6%	5.1%	-0.4%	79.5%	5.3%	5.5%	-0.1%	79.7%
Domestic	36.1%	6.4%	5.8%	0.5%	82.4%	6.9%	6.8%	0.1%	80.8%

[1]% of industry RPKs in 2018 [2]Year-on-year change in load factor [3]Load factor level

Air Passenger Market Analysis – February 2019 1

> SAF Dan Tsubouchi @Energy_Tidbits · Mar 21
>
> 
>
> Bullish for near term #Oil.
>
> ***"we're seeing jet fuel now back to averaging around 6.9 million barrels per day over the last 4-weeks, which is back to 2019 levels"*** ...

8 25 6.2K

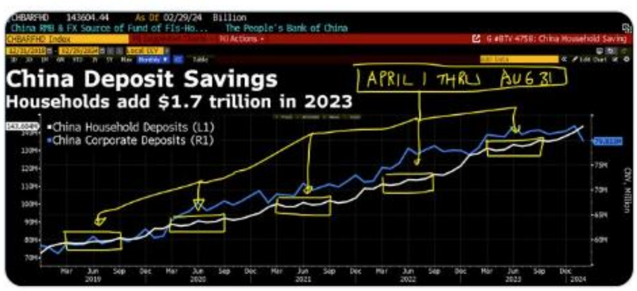
SAF Dan Tsubouchi @Energy_Tidbits · Apr 4

Boost to China economy coming Apr 1?

Yes, households continued to add to savings in Feb.

But don't forget Apr is start of high season and Chinese households normally increase spending every Apr 1 thru Aug 31.

Thx @business #OOTT



5 8 2.4K

Dan Tsubouchi @Energy_Tidbits · Apr 3

Positive for Cdn #Oil prices.

590,000 b/d TMX expansion starts commercial operation May 1!

Canada's 1st direct access to global oil markets.

#OOTT

https://www.transmountain.com/news/2024/trans-mountain-successfully-completes-pipe-pullback-for-mountain-3-hdd-and-provides-operational-update

Trans Mountain Successfully Completes Pipe Pullback for Mountain 3 HDD and Provides Operational Update

Home › News

Apr. 3, 2024

On March 29, 2024, Trans Mountain successfully completed the pipe pullback for the Mountain 3 Horizontal Directional Drill (HDD) in the Fraser Valley between Hope and Chilliwack, BC.

To complete the Expansion Project, there are several remaining steps including obtaining outstanding approvals from the Canada Energy Regulator (CER). With the appropriate approvals and completion of remaining construction activity, Trans Mountain will commence transporting crude oil on the expanded system.

The Commencement Date for commercial operation of the expanded system will be May 1, 2024. Trans Mountain anticipates providing service for all contracted volumes in the month of May.

After commencement of operation of the Expansion Project, Trans Mountain will continue cleanup, reclamation, road and civil work.

1 5 28 4.1K

Dan Tsubouchi @Energy_Tidbits · Apr 3

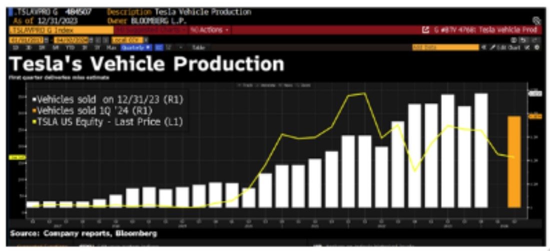
Peak #Oil Demand pushed back?

Surely IEA has to lower its EV growth rate in its upcoming Global EVs Outlook 2024 and its forecast that EVs displace ~5.5 mmb/d of oil demand by 2030.

Or can they ignore EV global leaders, Tesla & BVD, both having big QoQ sales declines?

#OOTT

> **Dan Tsubouchi** @Energy_Tidbits · Apr 2
>
> ICYMI.
>
> Tesla shares down ~5%, delivered 386,810 vehicles in Q1/24, big miss vs analyst estimates, which were lowered in last two weeks.
>
> ...
>
> Show more



2 · 19 · 4.1K

Dan Tsubouchi @Energy_Tidbits · Apr 3

For those not near their laptop, @EIAgov just released at 8:30am MT its #Oil #Gasoline #Distillates inventory as of Mar 29. Table below compares EIA data vs @businessexpectations and vs @APIenergy yesterday. Prior to release, WTI was $85.85. #OOTT

Oil/Products Inventory Mar 29: EIA, Bloomberg Survey Expectations, API

(million barrels)	EIA	Expectations	API
Oil	3.21	-1.00	-2.29
Gasoline	-4.26	0.10	-1.42
Distillates	-1.27	-1.00	-2.55
	-2.32	-1.90	-6.26

Note: Oil is commercial. So excludes a +0.6 mmb in SPR for the Mar 29 week

Note: Included in the oil data, Cushing had a 0.378 mmb draw for Mar 29 week

Source EIA, Bloomberg

Prepared by SAF Group https://safgroup.ca/news-insights/

3 · 11 · 1.7K

Dan Tsubouchi @Energy_Tidbits · Apr 3

Positive for #Oil

"***Chinese onshore oil stocks are actually very low. They drew down a lot over the first 3 months of this year***".

"*flows to China over the whole maintenance period will be pretty steady between 9-10 mmb/d*"

@kpler @mattwright8 to @sean_evers @gulf_intel.

...

Show more

"… Chinese onshore oil stocks are actually very low. They drew down a lot over the first 3 months of this year". **Matthew Wright, Senior Freight Analyst, Kpler.**

SAF Group created transcript of comments by Matthew Wright (Senior Freight Analyst, Kpler) with Sean Evers (Founder and Managing Partner Gulf Intelligence) on Gulf Intelligence Daily Energy Markets April 3 podcast. [LINK]

Items in "*italics*" are SAF Group created transcript.

At 12:00 min mark, Evers "*… China isn't as bad as the headlines in the first quarter were kind of indicating. Pre China new year, there was a lot of bearish narrative around China's recovery. Generally it looks like its obviously not stellar but it's clearly not in the doghouse. What are we seeing from a shipping point of view coming around China, any of the flows that give us some indication as to the health of the Chinese economy?*" Wright "*Yeah, very good question. I think you're right. Yes, there's still some real issues in the property sector but they've really invested into manufacturing and into industry which are actually sort of greater use, have a great use of oil products. So, we're heading into Chinese peak refinery maintenance season over the spring and, actually, crude exports to China haven't declined as much as you would perhaps have seen in other years. And part of the reason for this is Chinese onshore oil stocks are actually very low. They drew down a lot over the first 3 months of this year. So there is good reason to suspect that crude flows to China over this whole maintenance period will be pretty steady between 9 to 10 million barrels a day, which is going to support the market. That is a very important outflow from the Middle East in particular.*"

Prepared by SAF Group. https://safgroup.ca/news-insights/

3 23 57 8.9K

Dan Tsubouchi @Energy_Tidbits · Apr 2

"*This is just a ridiculously inexpensive name*" @ericnuttall re Precision Drilling on @BNNBloomberg just <1pm ET.

Don't normally see such an immediate jump in volume & price. PD shares +4.3% basically all after his call. FYI, he disclosed bought 9.9% over past few mths.

#OOTT

1 2 10 2.6K

Dan Tsubouchi @Energy_Tidbits · 1h

Great map reminds Ukraine has capability to hit all Russia #Oil/#LNG export terminals on Baltic & Black Seas.

This potential risk was on @CroftHelima 👇 03/27 Must Read temperature rising risks comment.

Thx @SPGlobal Kelly Norways, Elza Turner
#OOTT


Strike on Russia's Taneco refinery marks leap in Ukrainian drone radius

HIGHLIGHTS

Ukraine's longest-range drone strike to date at 1,115 km

Confirms strike range that threatens nearby Taif refinery

Strikes have impacted 1.6 million b/d capacity so far

Author Kelly Norways, Elza Turner

Dan Tsubouchi @Energy_Tidbits · Mar 31

This 👇 Must Read from @CroftHelima looks even more relevant with the last 4 days, incl last night, of escalating Russia drone attacks on Ukraine energy/power infra.

Will Ukraine expand its drone attacks to target RUS oil export facilities...

7 · 1.8K

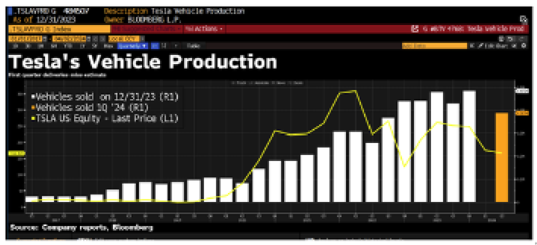
Dan Tsubouchi @Energy_Tidbits · 4h

ICYMI.

Tesla shares down ~5%, delivered 386,810 vehicles in Q1/24, big miss vs analyst estimates, which were lowered in last two weeks.

Tesla has the big big cost advantage relative to other EV makers but it's a sign of a tough EV market when the top brand is hit.

#OOTT



1 1 4 1.3K

Dan Tsubouchi @Energy_Tidbits · 10h

Iran Supreme Leader "*The evil regime will be punished by our brave men*"

Iran President "*this cowardly crime will not go unanswered*"

Per state media.

How/when will Iran retaliate vs Israel?

Brent currently +$1.50 to $88.92.

...

Show more

Dan Tsubouchi @Energy_Tidbits · 21h

Breaking!

Increasing geopolitical risk Iran/Israel/US.

Iran message to US via Swiss re Israel bombing of Ira...

2 · 6 · 3K

SAF

Dan Tsubouchi @Energy_Tidbits · 20h

More Ammonia = More #NatGas

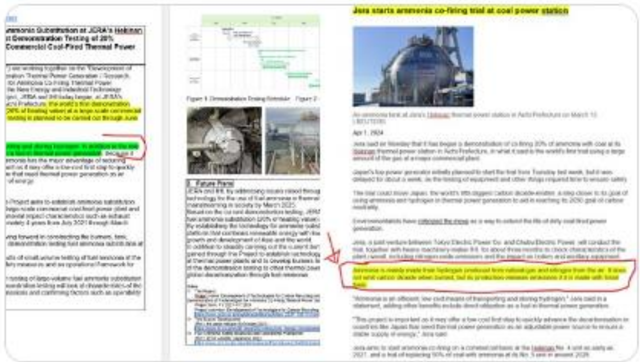
JERA tests 20% Ammonia substitution at Coal thermal power plant.

Says Ammonia is means of transporting Hydrogen.

BUT recall 👇 01/21/22, hydrogen must be produced from another substance.

JERA forgot to highlight the hydrogen is coming from #NatGas...

Show more



SAF **Dan Tsubouchi** @Energy_Tidbits · Jan 21, 2022

"takes more energy to produce #hydrogen (by separating it from other elements in molecules) than hydogren provides when it is converted to useful energy" "an energy carrier that must be produced from another substance". nice to see @EIAgov give facts n...

1 · 2 · 5 · 4.1K

Dan Tsubouchi @Energy_Tidbits · 21h

Breaking!

Increasing geopolitical risk Iran/Israel/US.

Iran message to US via Swiss re Israel bombing of Iran consulate in Syria.

"important message was sent to the US govt as a supporter of the Zionist regime, the Foreign Minister said, "America must be held accountable."...

Show more

Warning: Important message was sent to the US government.

> **Dan Tsubouchi** @Energy_Tidbits · Apr 1
>
> Breaking!
>
> How/what will Iran do in retaliation?
>
> @AJEnglish "Israeli strikes have hit Syria's capital, ...

2 · 7 · 19 · 7.2K

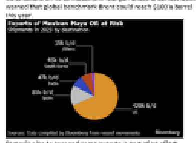
Dan Tsubouchi @Energy_Tidbits · Apr 1

Less MEX #Oil to PADD 3 = Positive to Cdn oil

Pemex canceled some export contracts, incl to PADD 3, as 340 kbp Olmeca refinery ramps up. @lkassai

Plus Q2 start of 590 kbd Trans Mountain TMX expansion will move Cdn oil to Asia.

Biden needs 👇 155 kbd VEN oil to Padd 3. #OOTT



6 · 16 · 3.8K

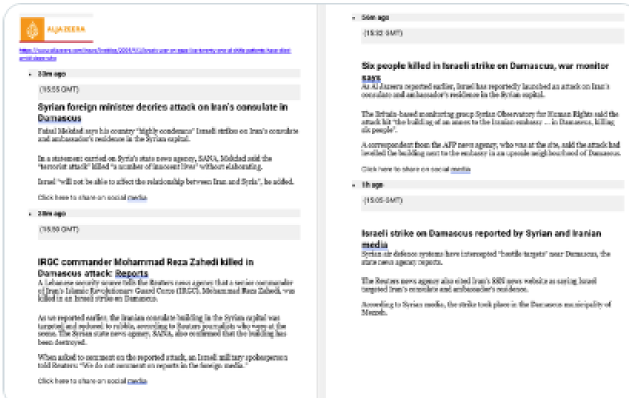
Dan Tsubouchi @Energy_Tidbits · Apr 1

Breaking!

How/what will Iran do in retaliation?

@AJEnglish "Israeli strikes have hit Syria's capital, Damascus, in an attack on Iran's consulate and the ambassador's residence, killing at least six people, according to the Syrian Observatory for Human Rights"

#OOTT



ALJAZEERA

- 20m ago

(15:55 GMT)

Syrian foreign minister decries attack on Iran's consulate in Damascus

Faisal Mekdad says his country "highly condemns" Israeli strikes on Iran's consulate and ambassador's residence in the Syrian capital.

In a statement carried on Syria's state news agency, SANA, Mekdad said the "terrorist attack" killed "a number of innocent lives" without elaborating.

Israel "will not be able to affect the relationship between Iran and Syria", he added.

Click here to share on social media

- 28m ago

(15:50 GMT)

IRGC commander Mohammad Reza Zahedi killed in Damascus attack: Reports

A Lebanese security source tells the Reuters news agency that a senior commander of Iran's Islamic Revolutionary Guard Corps (IRGC), Mohammad Reza Zahedi, was killed in an Israeli strike on Damascus.

As we reported earlier, the Iranian consulate building in the Syrian capital was targeted and reduced to rubble, according to Reuters journalists who were at the scene. The Syrian state news agency, SANA, also confirmed that the building has been destroyed.

When asked to comment on the reported attack, an Israeli military spokesperson told Reuters: "We do not comment on reports in the foreign media."

Click here to share on social media

- 56m ago

(15:32 GMT)

Six people killed in Israeli strike on Damascus, war monitor says

As Al Jazeera reported earlier, Israel has reportedly launched an attack on Iran's consulate and ambassador's residence in the Syrian capital.

The Britain-based monitoring group Syrian Observatory for Human Rights said the attack hit "the building of an annex to the Iranian embassy ... in Damascus, killing six people".

A correspondent from the AFP news agency, who was at the site, said the attack had levelled the building next to the embassy in an upscale neighbourhood of Damascus.

Click here to share on social media

- 1h ago

(15:05 GMT)

Israeli strike on Damascus reported by Syrian and Iranian media

Syrian air defence systems have intercepted "hostile targets" near Damascus, the state news agency reports.

The Reuters news agency also cited Iran's SNN news website as saying Israel targeted Iran's consulate and ambassador's residence.

According to Syrian media, the strike took place in the Damascus municipality of Mezzeh.

1 4 10 6.3K

Dan Tsubouchi @Energy_Tidbits · Apr 1

April is shoulder season for #NatGas so no significant weather driven demand for #NatGas

Generally it's leave the windows open temperature.

Not cold enough to crank up the furnace or not hot enough to crank up the air conditioning.

Thx @NOAA

...

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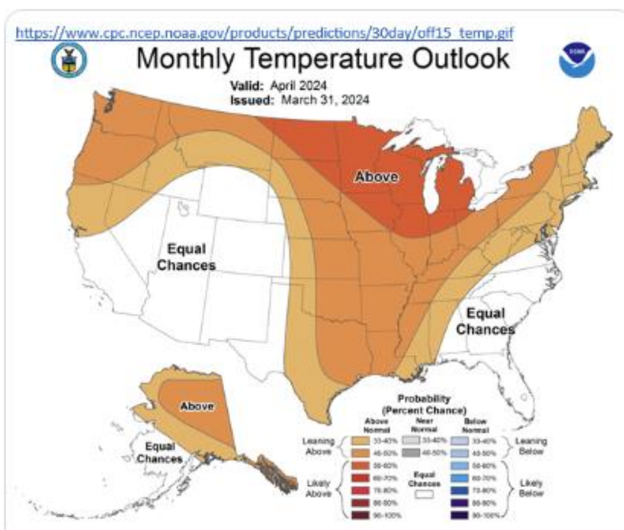


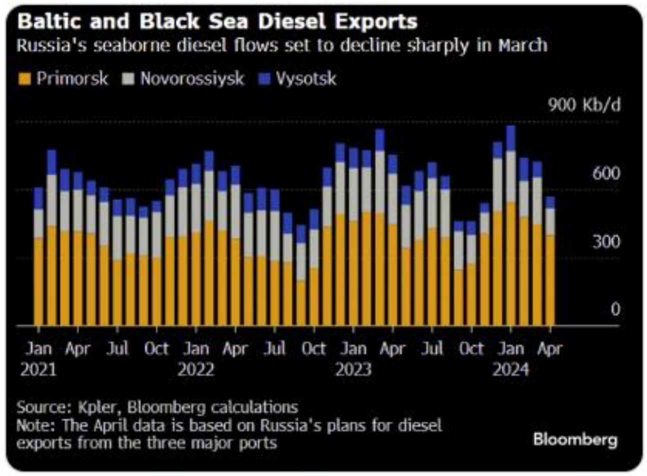
3 11 2.3K

Dan Tsubouchi @Energy_Tidbits · Apr 1

Russia #Diesel loadings down 155,000 b/d MoM to 569,000 b/d in April from RUS 3 major Black & Baltic Sea ports.

Drone hits on multiple RUS refineries is cutting diesel production so less available for export.

Thx @ja_herron @Kpler
#OOTT



3 11 1.4K

Dan Tsubouchi @Energy_Tidbits · Mar 31

5th straight month of expansion for China smaller & export oriented firms.

China Caixin Manufacturing PMI Mar 51.1 (est 51.0), Feb 50.9, Jan 50.8, Dec 50.8, Nov 50.7, Oct 49.5.

"*incoming new orders, incl export orders, grew at accelerated rates...*"

Thx @SPGlobalPMI. #OOTT

> **Dan Tsubouchi** @Energy_Tidbits · Mar 31
>
> 
>
> Positive for #Oil
>
> 1st expansion in official China Manufacturing PMI since Sept.
>
> ...

4 · 20 · 4.8K