Types of high speed trains: Bullet, TGV, MagLev, MaglevSC

Maglev In the Beginning

Maglev -- short for magnetic levitation -- trains can trace their roots to technology pioneered at Brookhaven National Laboratory. Brookhaven National Laboratory is a United States Department of Energy national laboratory located in Upton, Long Island, and was formally established in 1947

James Powell and Gordon Danby of Brookhaven received the first Bullet Trains patent for a magnetically levitated train design in the late 1960s. The idea came to Powell as he sat in a traffic jam, thinking that there must be a better way to travel on land than cars or traditional trains. He dreamed up the idea of using superconducting magnets to levitate a train car. Superconducting magnets are electromagnets that are cooled to extreme temperatures during use, which dramatically increases the power of the magnetic field.

The first commercially operated high-speed superconducting Maglev train opened in Shanghai in 2004, while others are in operation in Japan and South Korea. In the United States, a number of routes are being explored to connect cities such as Baltimore and Washington, D.C.

OR

https://www.britannica.com/technology/maglev-train

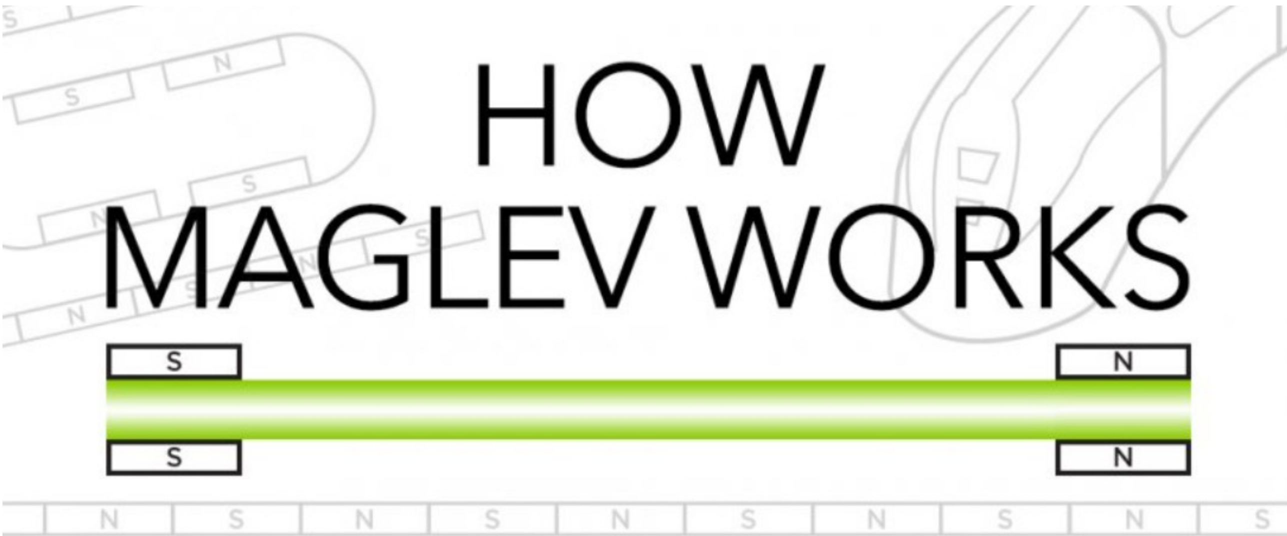
Maglevs were conceptualized during the early 1900s by American professor and inventor Robert Goddard and French-born American engineer Emile Bachelet and have been in commercial use since 1984, with several operating at present and extensive networks proposed for the future.

Maglev propulsion and levitation may involve the use of superconducting materials, electromagnets, diamagnets, and rare-earth magnets.

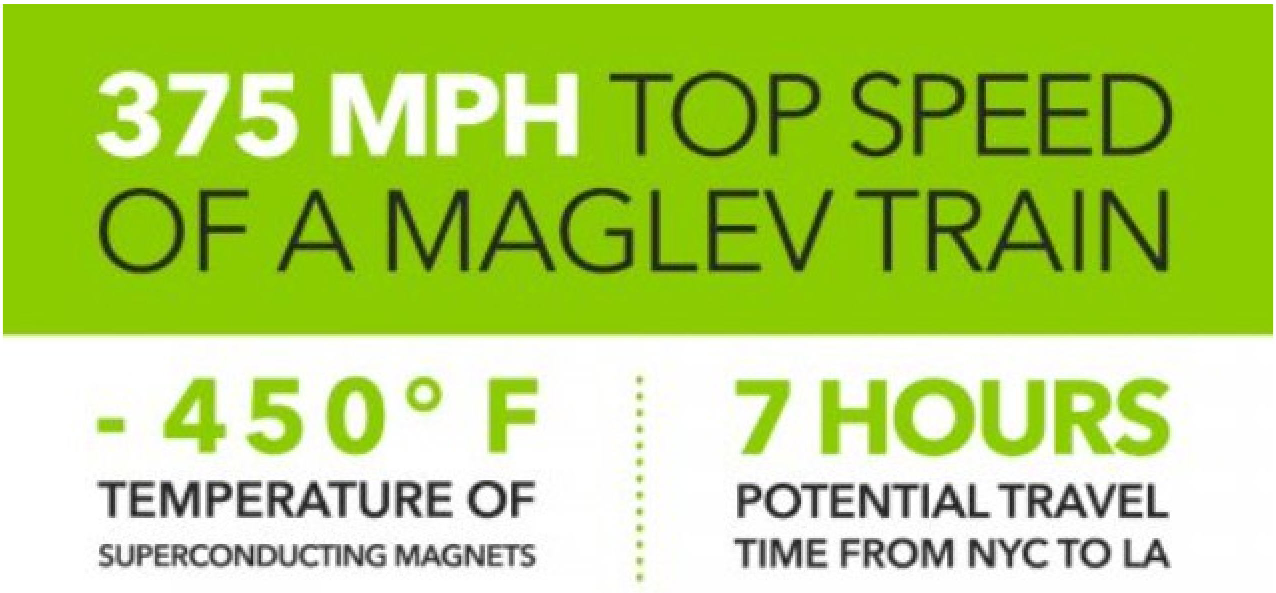
As of 2018 only six commercial maglev systems are currently in operation around the world. One is located in Japan, two in South Korea, and three in China. In Aichi, Japan, near Nagoya, a system built for the 2005 World's Fair, the Linimo, is still in operation. https://www.maglev.net/six-operational-maglev-lines-in-2018

In 1984, the first commercial maglev came on line in Birmingham, England. From 1984 to 1995, a low-speed maglev connected Birmingham International Airport to Birmingham International railway station.

VIDEO – Complete Physics of MAGLEV Trains



What if you could travel from New York to Los Angeles in just under seven hours without boarding a plane? It could be possible on a Maglev train.



NOTE: Absolute zero, temperature at which a thermodynamic system has the lowest energy. It corresponds to −273.15 °C on the Celsius temperature scale and to −459.67 °F on the Fahrenheit temperature scale.

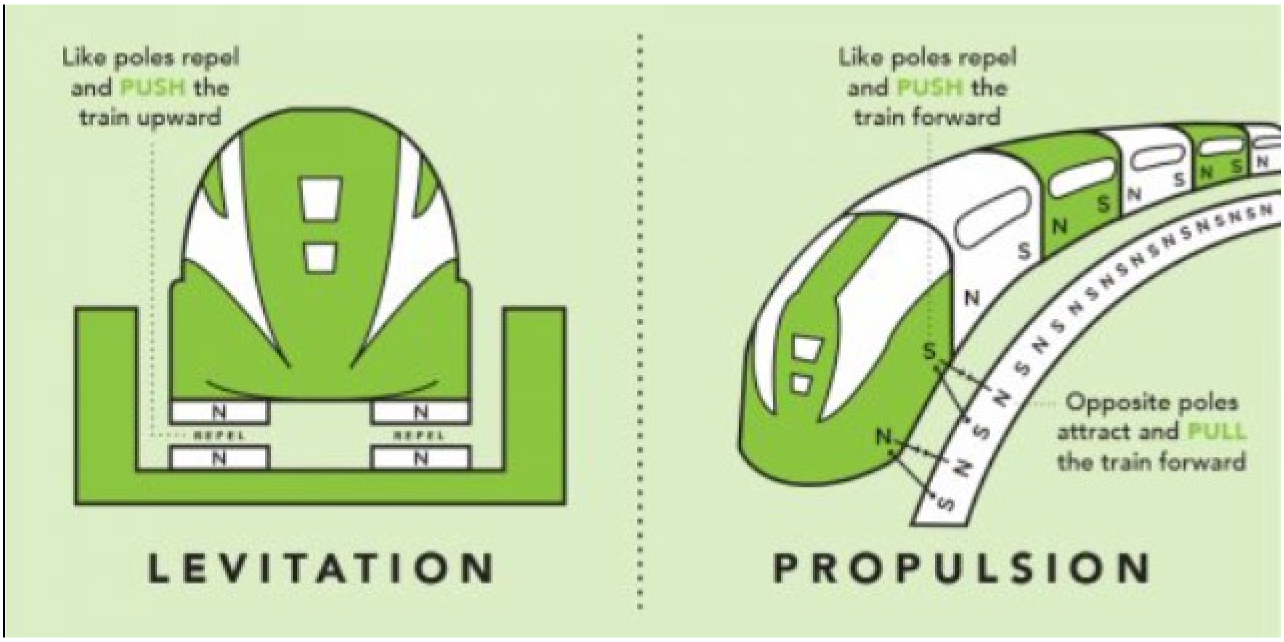
How Maglev works

In Maglev, superconducting magnets suspend a train car above a U-shaped concrete guideway. Like ordinary magnets, these magnets repel one another when matching poles face each other.

"A Maglev train car is just a box with magnets on the four corners," says Jesse Powell, the son of the Maglev inventor, who now works with his father. It's a bit more complex than that, but the concept is simple. The magnets employed are superconducting, which means that when they are cooled to less than 450 degrees Fahrenheit below zero, they can generate magnetic fields up to 10 times stronger than ordinary electromagnets, enough to suspend and propel a train.

These magnetic fields interact with simple metallic loops set into the concrete walls of the Maglev guideway. The loops are made of conductive materials, like aluminum, and when a magnetic field moves past, it creates an electric current that generates another magnetic field.

Three types of loops are set into the guideway at specific intervals to do three important tasks: one creates a field that makes the train hover about 5 inches above the guideway; a second keeps the train stable horizontally. Both loops use magnetic repulsion to keep the train car in the optimal spot; the further it gets from the center of the guideway or the closer to the bottom, the more magnetic resistance pushes it back on track.



The third set of loops is a propulsion system run by alternating current power. Here, both magnetic attraction and repulsion are used to move the train car along the guideway. Imagine the box with four magnets -- one on each corner. The front corners have magnets with north poles facing out, and the back corners have magnets with south poles outward. Electrifying the propulsion loops generates magnetic fields that both pull the train forward from the front and push it forward from behind.

This floating magnet design creates a smooth trip. Even though the train can travel up to 375 miles per hour, a rider experiences less turbulence than on traditional steel wheel trains because the only source of friction is air.

Another big benefit is safety. Maglev trains are “driven” by the powered guideway. Any two trains traveling the same route cannot catch up and crash into one another because they’re all being powered to move at the same speed. Similarly, traditional train derailments that occur because of cornering too quickly can’t happen with Maglev. The further a Maglev train gets from its normal position between the guideway walls, the stronger the magnetic force pushing it back into place becomes.

This core feature is what’s most exciting to Jesse Powell. “With Maglev, there is no driver. The vehicles have to move where the network sends them. That’s basic physics. So now that we have computer algorithms for routing things very efficiently, we could change the scheduling of the entire network on the fly. It leads to a much more flexible transportation system in the future,” he said.

While this exciting technology isn’t deployed in the United States today, if Powell and his team get their way, you could someday be floating your way to your next destination.

Editor’s Note: This post was written by a science writer at Brookhaven National Laboratory, one of the Department of Energy’s 17 National Labs.

2012 Cambridge Physics Study Booklet and Test -How mag;ev works
https://www.cambridgeinternational.org/images/156337-june-2012-pre-released-material-2.pdf

QUESTIONS NOT YET ANSWERED??

Is the max speed 375 mph? WHY? Wind resistance?

QUESTIONS ANSWERED

How does the train slow down/stop?

In a maglev system, the train is not only held up by magnets (often using some superconducting electromagnets) but also pulled forward by these magnets. Air friction will gradually slow the train down if the changing electromagnets aren't timed to pull it forward.

If the train needs to be stopped more quickly, the same magnets that pull it forward can be set to push it back. When they do, instead of requiring electrical energy input, they generate electrical energy output, which can be stored in batteries for later use. A similar system is used on some hybrid cars with electrical motors. When braking, the motor converts the mechanical energy of the car's motion back to electrical energy.

Example/experiment. Take a small battery powered dc electric motor. Disconnect the battery and replace it with a small resistor. Now turn the axle. There should be a measurable voltage across the resistor. The same device that converts electrical energy to mechanical energy can work in reverse to convert mechanical energy to electrical.

Maglev trains, which ordinarily have wheels as back-up for when the maglev fails, also have conventional brakes on the wheels for emergencies.

Do some maglev trains have superconducting magnets and others don't? Yes. Japan's newest does, electrodynamic suspension (EDS) uses superconducting magnets; others don't. Electromagnetic suspension (EMS).

Superconductor magnets vs regular magnets

https://www.researchgate.net/post/Do-MAGLEV-trains-use-superconductors-to-float-or-electromagnets-in-the-train

3rd Apr, 2015 David Cope Engineering Matters Inc.
There can be (a) train-borne superconductors for large-gap (10cm) designs (Japanese) or, alternatively, (b) train-borne electromagnets for small gap (1cm) designs (Germans, Chinese). In either case, the magnets can be used for levitation, guidance and propulsion. The thrust comes from an active track, that is coils in the guideway are sequentially excited (like a linear motor) to pull and push on the train superconductors or electromagnets. There are many possible magnetic configurations.

4th Apr, 2015 Carl Snyder New Hampshire University
Both configurations can be used, but the closer you get the train to the "rail" the better because you can increase velocity.

Hyperloop
Creating a vacuum between the entire system, between the surface of the train and its environment, the tunnel eliminates the air resistance and allows for extreme speeds, - thousands of miles per hour. The downsides of this are: tiny bits of debris can rip through the train leading to explosive decompression; additionally, if the tunnel breeches to the open environment around it allowing air molecules to penetrate the system there would be an extreme acceleration towards 0, and this would act much like an object hitting the atmosphere burning up. Potentially acting similar to an asteroid hitting a thicker layer of atmosphere resulting in a massive explosion. This would happen because the velocity the penetrating air would fill the vacuum tunnel would be just as great as the velocity of the train and this would lead to increased psi, 2-4 atmospheres.

The Magnaplane--the first and arguably the best Maglev concept--was invented by Prof. Henry Kolm at MIT and Princeton in the 1970's. A scale model was built and tested to demonstrate the concept. The Magnaplane uses superconductors (SC) aboard the train to create an intense magnetic field (~10 teslas). The train runs in a high-conductivity aluminum tube. Below 5 to 20 mph, the train travels on rubber tires. Above 5-20 mph. the SC magnets aboard the train induce sufficient (repulsive) eddy currents in the aluminum beneath the train to levitate the train ~10 cm above the track. The vertical position of the Magnaplane is inherently stable. One preferred option is to operate the Magnaplane in a fully- or partially-evacuated tube. (The concept of using an evacuated tube in a subway system was used in the very first mile of the New York City subway system in the ~1880 or ~1890. See an article in the Smithsonian Magazine.) In the 1980's, I designed and analyzed lateral, vertical, and longitudinal stabilization systems for the Magnaplane system.
The German design uses vertical attraction magnets between lower-field, resistive, electromagnets aboard the train, and an iron rail ~0.5 to 1.0 cm located above the electromagnets. Such a system is inherently unstable, so rapid, powerful feedback circuits aboard the train are required to maintain stability. Furthermore, the iron "rails" must be meticulously positioned so that the train never contacts the rails. This system is used in a high-speed rail system between Hamburg and Berlin

https://www.alphr.com/technology/1006815/how-hyperloop-works-launch-magnetic-levitation/
May 2014 https://newatlas.com/1800mph-maglev/32213/

Scientists at Southwest Jiaotong University in China have reportedly built a maglev train that could reach 1,800 mph (2,900 km/h). According to The Daily Mail, a vacuum is used to minimize air resistance. Project lead Dr Deng Zigang claims it could be used for military or space launch systems.

At those sort of speeds, air resistance becomes a serious issue. The Mail article cites a paper by Zigang in which he writes, "If the running speed exceeds 400 kilometers (250 miles) per hour, more than 83 percent of traction energy will wastefully dissipate in air resistance." (NOTE: max speed now is 375 mph)

Traction energy is the energy required to propel a vehicle. Factors such as friction, wind drag, acceleration, and hill climb are forces that the vehicle must overcome. Traction energy is the name referring to the energy required to overcome these collective forces.

The idea of running a maglev train in a vacuum, therefore, seems a logical one. It would increase its potential top speed and improve its energy efficiency. This principle is the same as the one that the Evacuated Tube Transport is based, which could theoretically transport people between New York and Beijing in 2 hours.

https://en.wikipedia.org/wiki/Virgin_Hyperloop

The concept of Hyperloop transportation was first introduced by Robert H. Goddard in 1904.[5][6] The train was designed to run suspended by magnetic systems in a vacuum tube.[7] The company is currently working on projects around the world.

The original Hyperloop concept is proposed to use a linear electric motor to accelerate and decelerate an air-bearing levitated pod through a low-pressure tube. The vehicle would glide silently for miles at speeds up to 760 mph (1223.1 km/h) with very low turbulence.[8] The system is proposed to be entirely autonomous, quiet, direct-to-destination and on-demand. Additionally, as Hyperloop is proposed to be built on columns or tunneled underground, this could eliminate the dangers of at-grade crossings and require smaller rights of way than high-speed rail or a highway.[9] Virgin Hyperloop has made substantive technical changes to Elon Musk's initial proposal and chose not to pursue the Los Angeles–to–San Francisco notional route that Musk envisioned in his 2013 alpha-design white paper.

Video Virgin Hyperloop First Hyperloop Passenger Test Nov 9, 2020
https://www.youtube.com/watch?v=xKvbSboQ5_g&ab_channel=VirginHyperloop

Video The Race to Build the World's First Hyperloop
https://www.youtube.com/watch?v=luDqbIZGgQM&ab_channel=TheB1M

Hyperloop Explained
https://www.youtube.com/watch?v=zcikLQZI5wQ&ab_channel=TheB1M

Hyperloop Benefits
maglev inside a vacuum tunnel (eliminating air friction, weather and track obstacles)
much faster speed (1,800 mph design ongoing in China)

Hyperloop Costs/Disadvantages
the tunnel adds expense to the tracks
dangers added with higher speeds:

- explosive decompression
- if the tunnel breeches to the open environment that would act much like an object hitting the atmosphere burning up.

What are the 2 types of maglev trains? EMS and EDS

Electromagnetic suspension (EMS) and electrodynamic suspension (EDS) Two types of maglevs are in service. Electromagnetic suspension (EMS) uses the attractive force between magnets present on the train's sides and underside and on the guideway to levitate the train.

https://www.britannica.com/technology/maglev-train

Why are superconducting magnets used in maglev train Hyperloop technology?

EMS uses electronically controlled electromagnets in the train to attract it to a magnetic steel track, while EDS uses superconducting electromagnets on both the train and the rail to produce a mutually repellent force that makes the carriages levitate. ... This is also known as passive magnetic levitation technology.

There are two primary types of maglev technology: electromagnetic suspension (EMS) uses the attractive magnetic force of a magnet beneath a rail to lift the train up. electrodynamic suspension (EDS) uses a repulsive force between two magnetic fields to push the train away from the rail.

Electromagnetic suspension (EMS) and electrodynamic suspension (EDS)

Two types of maglevs are in service. Electromagnetic suspension (EMS) uses the attractive force between magnets present on the train's sides and underside and on the guideway to levitate the train. A variation on EMS, called Transrapid, employs an electromagnet to lift the train off the guideway. The attraction from magnets present on the underside of the vehicle that wrap around the iron rails of the guideway keep the train about 1.3 cm (0.5 inch) above the guideway.

Electrodynamic suspension (EDS) systems are similar to EMS in several respects, but the magnets are used to repel the train from the guideway rather than attract them. These magnets are supercooled and superconducting and have the ability to conduct electricity for a short time after power has been cut. (In EMS systems a loss of power shuts down the electromagnets.) Also, unlike EMS, the charge of the magnetized coils of the guideway in EDS systems repels the charge of magnets on the undercarriage of the train so that it levitates higher (typically in the range of 1–10 cm [0.4–3.9 inches]) above the guideway. EDS trains are slow to lift off, so they have wheels that must be deployed below approximately 100 km (62 miles) per hour. Once levitated, however, the train is moved forward by propulsion provided by the guideway coils, which are constantly changing polarity owing to alternating electrical current that powers the system.

Bullet trains TGV

Bullet trains and TGV (except TGV POS which is maglev) run on conventional tracks but newly built or retrofitted for high speed.

Speed Maglev and Bullet

The statistic illustrates the world's fastest high-speed trains as of January 2021, based on the maximum speed. Japan's high-speed train is at the top of the list: The L0 Series Maglev reaches 375 miles per hour.
https://en.wikipedia.org/wiki/Shanghai_maglev_train

Japan's speed record is 374mph Tokyo 2021
The SCMAGLEV has travelled hundreds of thousands of miles in its development on a 27 mile long track. This track represents the initial segment of a 220 mile line under current construction in Japan between Tokyo and Nagoya, and will eventually extend on to Osaka. The current SCMAGLEV train, known as the L0 (L-zero) holds the Guinness record for the world's fastest maglev train – clocking in at 374.68 mph (603 km/h).

Previously a Japanese Maglev, train held the world train speed record of 361 mph (581 kph) reached in 2003.   Max Speed so far 600 kph 376 mph

China's speed record is 373mph Qingdao 2021 (not yet in operation)
https://edition.cnn.com/travel/article/china-highspeed-maglev-prototype/index.html

> China first unveiled the train prototype back in 2019 when it announced their maglev train would transport passengers from beijing to shanghai in about 3.5 hours. compared to the 4.5 hours by plane and 5.5 hours by high-speed rail, this seems to be a huge achievement. the only problem is that currently, china only has one maglev line in commercial use — one connecting shanghai's udon airport with the city's longing road station. according to CNN, '*several new maglev networks are reportedly under construction, including one linking shanghai and hangzhou and another connecting chengdu and chongqing.*'

https://www.designboom.com/technology/china-maglev-train-600-km-hour-08-30-2021/

France's TGV POS has a speed limit of just over 357 mph (575 kph)
The TGV POS is a TGV train built by French manufacturer Alstom which is operated

by the French national rail company, the SNCF, in France's high-speed rail lines. It was originally ordered by the SNCF for use on the new LGV Est, which was put into service in 2007. "POS" stands for Paris-Ostfrankreich-Süddeutschland.

The train is an experimental version of the Traine a Grande Vitesse (TGV), equipped with two supercharged locomotives and extra-large wheels. It easily beat the previous 515.3 kph record set by a TGV in 1990

French people have been enjoying 200 mph rail travel since 1981 with TGV, which stands for Train à Grande Vitesse ("high speed train" in English).
A type of TGV called V150 holds the record for the highest speed on any national rail system - it hit a whopping 357.2 mph (575 kph) in April 2007 making it the fastest conventional-wheeled train. TGV 4402 (operation V150) reaching 574 km/h on 3 April 2007 near Le Chemin, France. Operation V150, where 150 refers to a target speed in metres per second,

The first high-speed rail system, the Tōkaidō Shinkansen, began operations in Japan in 1964 and was widely known as the bullet train.

Fastest trains in the world by top speed 2021 - Statista
https://www.statista.com/statistics/557186/high-speed-trains-maxmimum-speed/

Benefits and Costs

The Benefits of Maglev Technology

- High Level Of Safety. Synchronized propulsion makes collisions between maglevs unimaginable
- No Derailment
- Reliability
- High-Speed
- Eco-Friendly
- The Quietest Transportation System
- Costs and Maintenance
- Energy Efficient

Maglevs eliminate a key source of friction—that of train wheels on the rails—although they must still overcome air resistance. This lack of friction means that they can reach higher speeds than conventional trains. At present maglev technology has produced trains that can travel in excess of 500 km (310 miles) per hour. This speed is twice as fast as a conventional commuter train and comparable to the TGV (Train à Grande Vitesse) in use in France, which travels between 300 and 320 km (186 and 199 miles) per hour. Because of air resistance, however, maglevs are only slightly more energy efficient than conventional trains.

Maglevs have several other advantages compared with conventional trains. They are less expensive to operate and maintain, because the absence of rolling friction means that parts do not wear out quickly (as do, for instance, the wheels on a conventional railcar). This means that fewer materials are consumed by the train's operation, because parts do not constantly have to be replaced. The design of the maglev cars and railway makes derailment highly unlikely, and maglev railcars can be built wider than conventional railcars, offering more options for using the interior space and making them more comfortable to ride in. Maglevs produce little to no air pollution during operation, because no fuel is being burned, and the absence of friction makes the trains very quiet (both within and outside the cars) and provides a very smooth ride for passengers. Finally, maglev systems can operate on higher ascending grades (up to 10 percent) than traditional railroads (limited to about 4 percent or less), reducing the need to excavate tunnels or level the landscape to accommodate the tracks.

The greatest obstacle to the development of maglev systems is that they require entirely new infrastructure that cannot be integrated with existing railroads and that would also compete with existing highways, railroads, and air routes.

While all large-scale transportation systems are expensive, maglev requires a dedicated infrastructure including substations and power supplies and cannot be integrated directly into an existing transportation system.

Besides the costs of construction, one factor to be considered in developing maglev rail systems is that they require the use of rare-earth elements (scandium, yttrium, and 15 lanthanides), which may be quite expensive to recover and refine. Magnets made from rare-earth elements, however, produce a stronger magnetic field than ferrite (iron compounds) or alnico (alloys of iron, aluminum, nickel, cobalt, and copper) magnets to lift and guide the train cars over a guideway.

The high cost of maglev systems results from the need for a stand-alone guideway construction featuring active magnetic coils embedded directly into the guideway or on the vehicle and, in the case of the Japanese design, the addition of very low temperature liquid cooled superconducting magnets.

While maglev prototypes and commercially operated maglev systems have demonstrated drastically reduced operating costs and carbon emissions, incompatibilities with existing rail infrastructure and $50-200 million per mile construction costs have become insurmountable impediments to mainstream adoption. The high cost of maglev systems results from the need for a stand-alone guideway construction featuring active magnetic coils embedded directly into the guideway or on the vehicle and, in the case of the Japanese design, the addition of very low temperature liquid cooled superconducting magnets.

http://www.magnetictransportsystems.com/maglevnotviable.shtml

Also the cooling system for superconducting magnets is expensive

Videos of Japan's maglev trains in operation
https://www.youtube.com/watch?v=_5FARo__YOs&ab_channel=HindustanTimes
https://edition.cnn.com/videos/world/2015/04/22/ct-japan-maglev-train-world-speed-record.cnn

East Coast Maglev
Keystone Corridor: Pittsburgh has the most advanced maglev initiative in the U.S. According to Transrapid, Inc.,
Baltimore-DC (study paused)
https://www.washingtonpost.com/transportation/2021/09/02/dc-baltimore-maglev-project-paused/

The Baltimore–Washington Superconducting Maglev Project (SCMAGLEV) is a proposed project connecting the United States cities of Baltimore, Maryland, and Washington, D.C., with a 40 mi (64 km) maglev train system between their respective central business districts. Put on hold 2021
https://en.wikipedia.org/wiki/Baltimore%E2%80%93Washington_Superconducting_Maglev_Project

West Coast Maglev
Las Vegas Project As of 2021, the United States has no maglev trains. Keystone Corridor: According to Transrapid, Inc., Pittsburgh has the most advanced maglev initiative in the U.S., followed by the Las Vegas project. Once federal funding is finalized, these two markets could be the first to see maglev in the United States.

San Diego Maglev
Designed and built here in San Diego, this is General Atomics' maglev or magnetic levitation train, operating since 2004 at their Sorrento Valley test track. With federal money now available for a variety of high-speed rail and maglev projects around the country, GA's work with maglev could soon be on its way to its first application. The cost estimate is approximately US$10 billion for the 120–150 km (80–100 mile) run, not including the cost of construction of the airport

San Diego Bullet
2006-2009 General Atomic was the first in the United States to build a full scale working maglev system, which operates on a 400-foot test track in San Diego, California. GA's Electromagnetic Systems Group (GA-EMS) provides design, prototyping and manufacturing capabilities for the Maglev system permanent

magnets and linear motors. The system was to run from San Francisco to the Los Angeles basin in under three hours at speeds capable of over 200 miles per hour. The system will eventually extend to Sacramento and San Diego, totaling 800 miles with up to 24 stations.
https://www.voiceofsandiego.org/topics/science-environment/a-new-maglev-train-finds-hope-in-a-stimulus-world/ Put on hold in 2009.

List of maglev train proposals worldwide
https://en.wikipedia.org/wiki/List_of_maglev_train_proposals

Bullet Trains
speed 320 mph
https://www.asdperu.com/ky4qruen/fastest-bullet-train-in-the-world-2021
cost much less

Batteries (a snippet)
by the side of the track
The plant in Garbce, with a capacity of 5.5 MW and a usable capacity of 1.2 MWh, is the largest energy storage facility working for traction purposes in Europe. The four containers use lithium-ion batteries made with NMC technology. This solution takes into account the nature of rail power, allowing the storage facility to charge slowly and release stored energy quickly when a train passes. The storage facility is capable of powering even the fastest trains, including Pendolino, within few seconds. At the heart of the storage facility is a DC/DC power converter that operates directly on DC/DC voltage, an innovative solution on a European scale.
https://ceek.pl/en/news/europes-largest-traction-energy-storage-facility-to-power-polish-green-railway