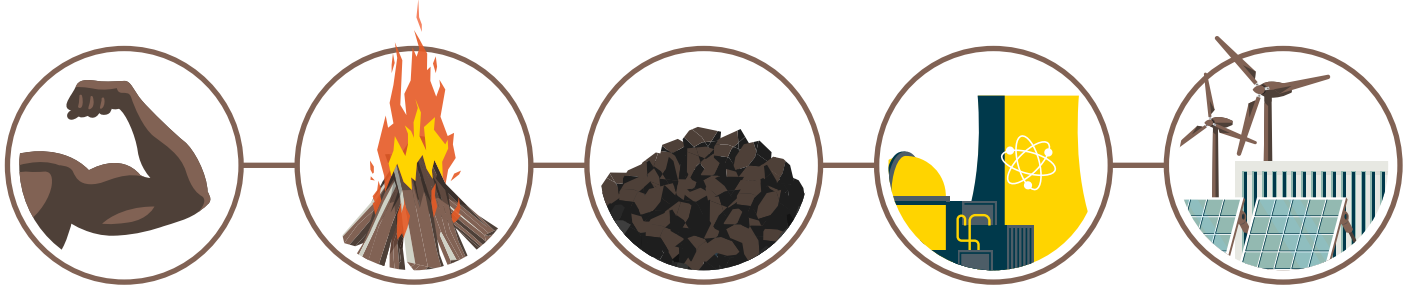
COPPER and the Clean Energy Transition

A new energy transition is beginning and copper is at the heart of it.

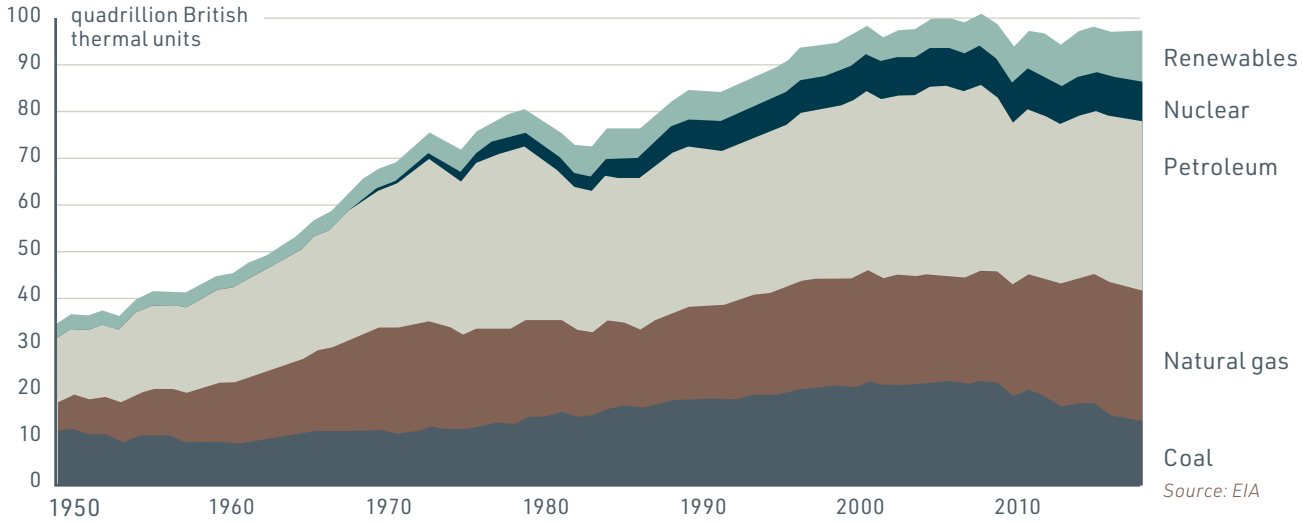


In the past two centuries, humankind has rapidly evolved its sources of power with each new scientific innovation, from muscle power and burning wood, to coal and nuclear fuel.

Energy Transitions

America's energy mix is rapidly diversifying.

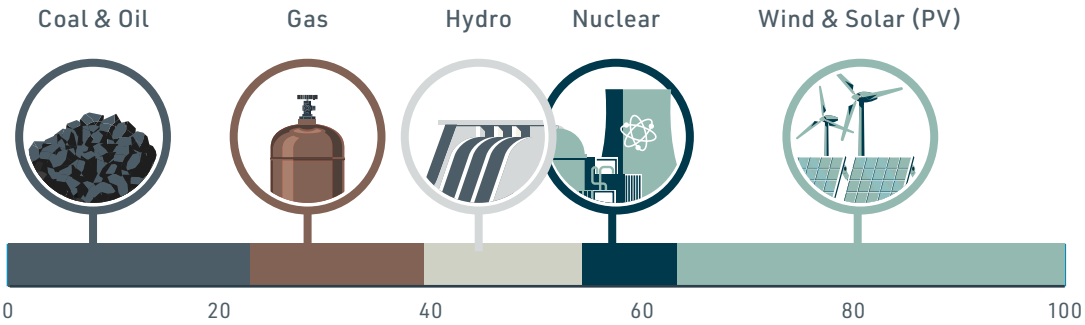
U.S. primary energy consumption (by major sources between 1950 and 2017)



Source: EIA

In the future, clean energy sources are set to take a larger portion of the global energy mix.

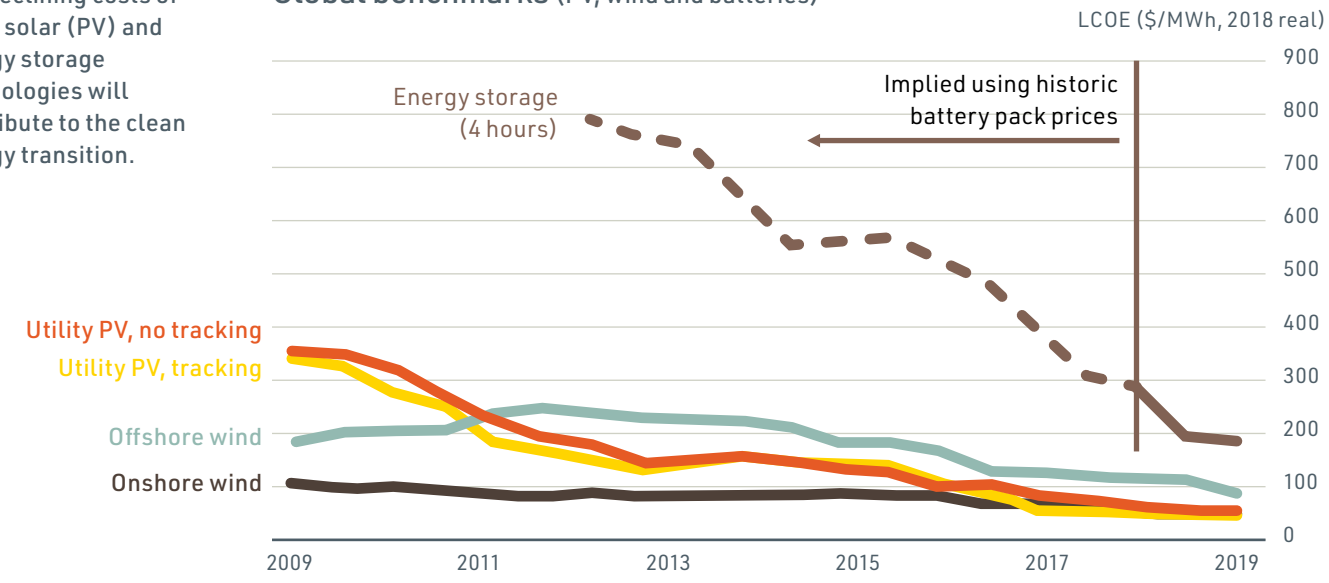
Power generation forecast Global electricity generation (% of total in 2040)



Source: Bloomberg New Energy Finance

The declining costs of wind, solar (PV) and energy storage technologies will contribute to the clean energy transition.

Global benchmarks (PV, wind and batteries)

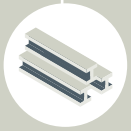


Source: Bloomberg New Energy Finance

With each energy transition comes a new need for materials.

Wind, solar, and the associated battery technologies are mineral intensive, using many niche and base metals.

Nickel

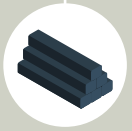


Lithium

Cobalt

Graphite

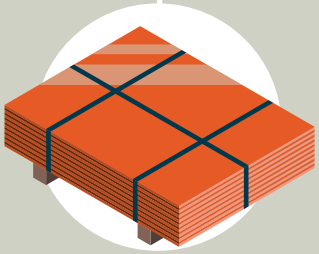
Aluminum



Vanadium

There is one metal that stands out:

Copper

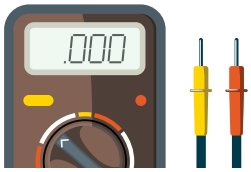


Copper connects and delivers clean energy to the world.

Why Copper?

Copper has the superior properties that allow it to be used for many types of clean energy.

CONDUCTIVITY

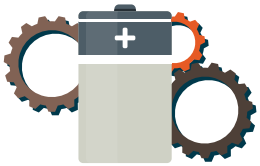


Electrons can move freely through copper, making it a good conductor of heat and electricity.

DUCTILITY

Copper's ability to be bent and easily shaped into wires or sheets, make it the ideal metal for a variety of electrical uses.

EFFICIENCY



Without copper, for the same efficiency, electrical equipment such as motors, transformers and cables would use 20% more materials.

RECYCLABILITY

Copper is 100% recyclable and can be used over and over without losing its engineering properties.

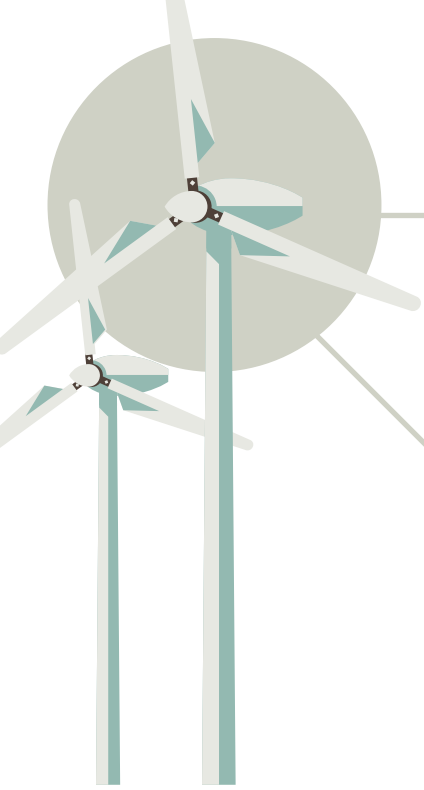
It is these properties that make it **the critical material** for wind and solar technology, energy storage, and electric vehicles.

The generation of clean energy from solar and wind has a copper usage that is typically

4-6 times

more than fossil fuels.

Source: ThinkCopper



Copper in Wind Farms

A 3 megawatts (MW) wind turbine contains up to

4.7 TONS OF COPPER.

53%	24%	4%	19%
CABLE AND WIRING	TURBINE/POWER GENERATION	TRANSFORMERS	TURBINE TRANSFORMER

Source: Navigant Research

Offshore wind farms require significantly more copper per MW on average than onshore wind farms, with copper cabling accounting for up to 82% of copper usage.

ONSHORE VS. OFFSHORE

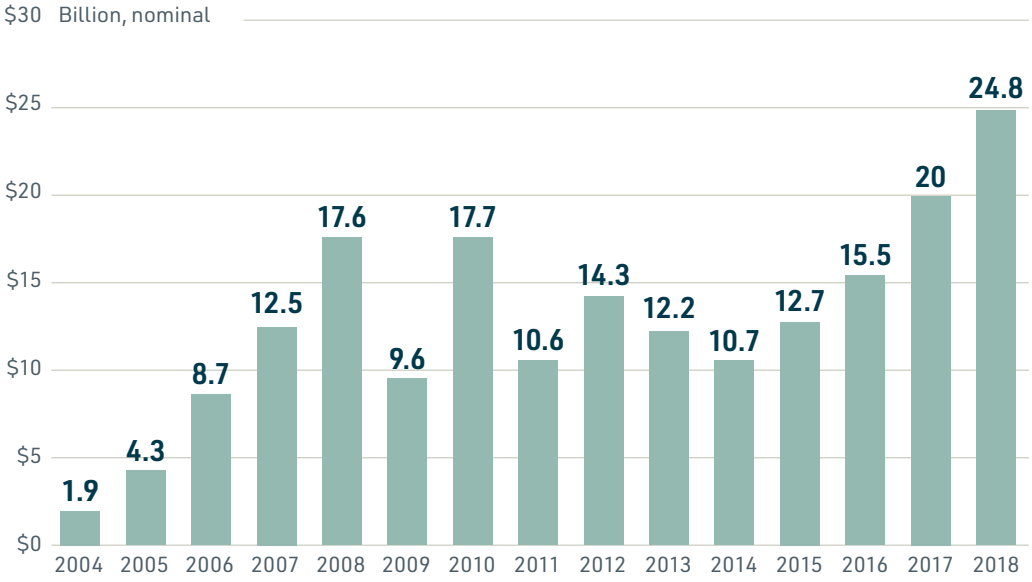
Onshore Wind Installations:
7,766 LBS
COPPER PER MW

Offshore Wind Installations:
21,067 LBS
COPPER PER MW

Source: Navigant Research

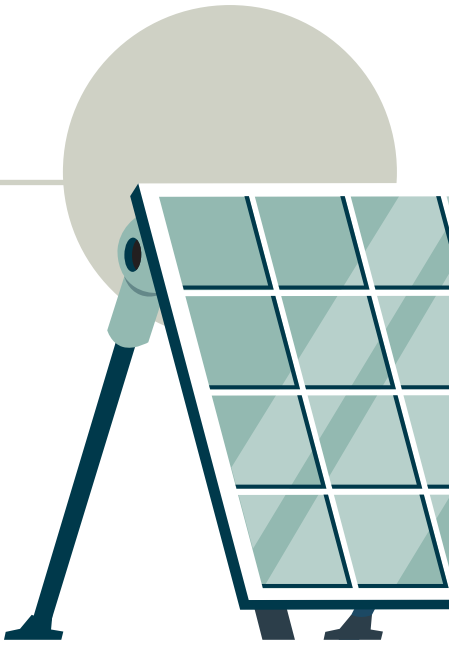
Since 2004, **$177 billion** has been invested in U.S. large-scale wind projects.

U.S. LARGE-SCALE WIND PROJECTS (financing)



Source: BloombergNEF Energy in America 2018

Copper in Solar Technology



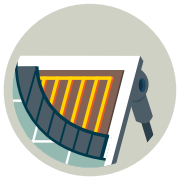
There are approximately

5.5 TONS PER MW

of copper in solar power systems.

Source: Navigant Research

Commonly used in



HEAT EXCHANGERS

Used to transfer solar energy to heat water or air in heating systems

WIRING

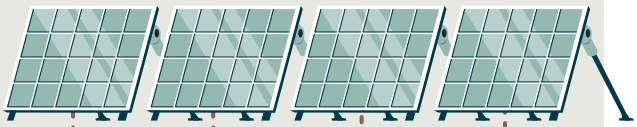
Used for conducting electricity

CABLING

A group of insulated conductors used for transmitting electrical power or signals

PROJECTED COPPER USAGE IN NORTH AMERICA

(from 2018 to 2027)

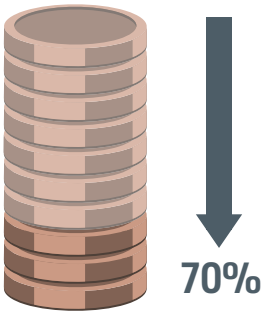


1.9 BILLION LBS of copper will be needed to power

262 GW of new solar installation

Source: Navigant Research

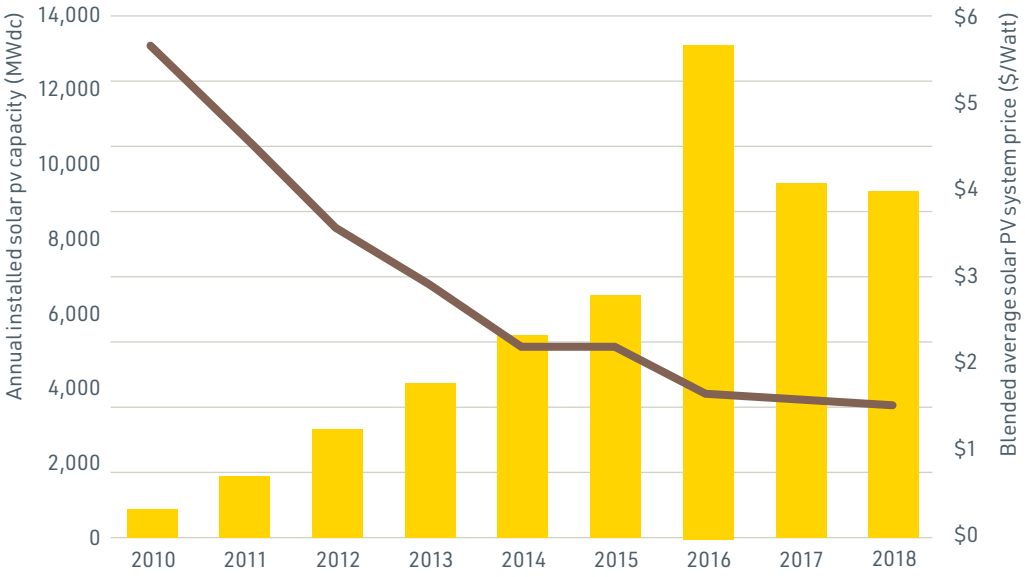
The cost to install solar has dropped by more than **70%** over the last decade which has **increased the annual installed capacity of solar power.**



70%

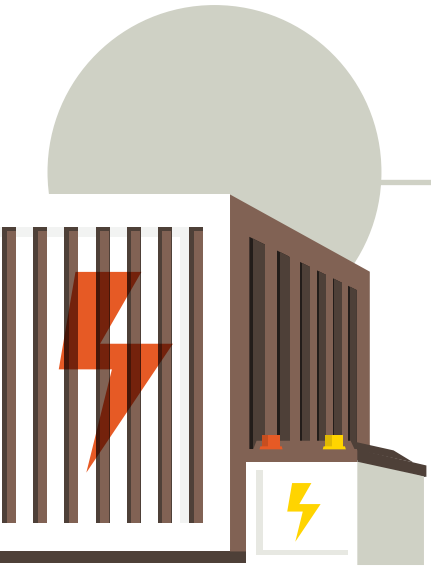
Source: SEIA

U.S. SOLAR PV price declines & deployment growth

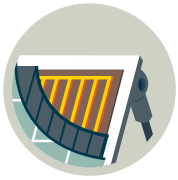


Source: SEIA

Copper in Energy Storage



Copper wiring and cabling connect renewable power generation with energy storage devices while the copper in the switches of transformers help to deliver power at the right voltage.

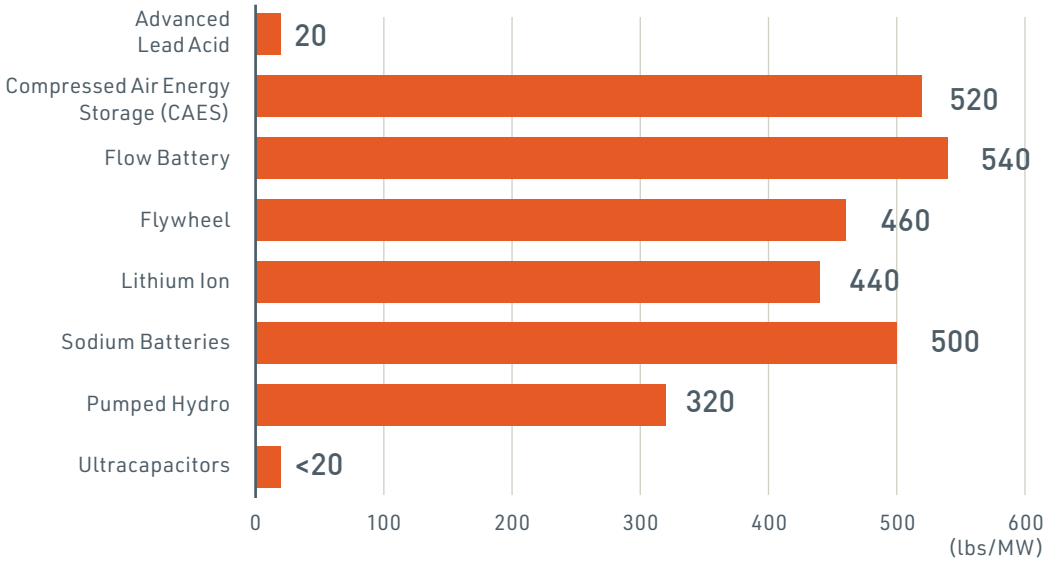


CABLING

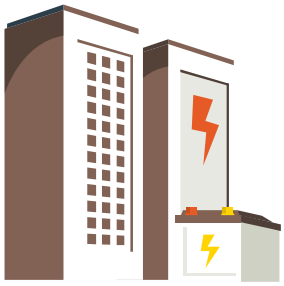
WIRING

SWITCHES

COPPER CONTENT (by Energy Storage Technology)



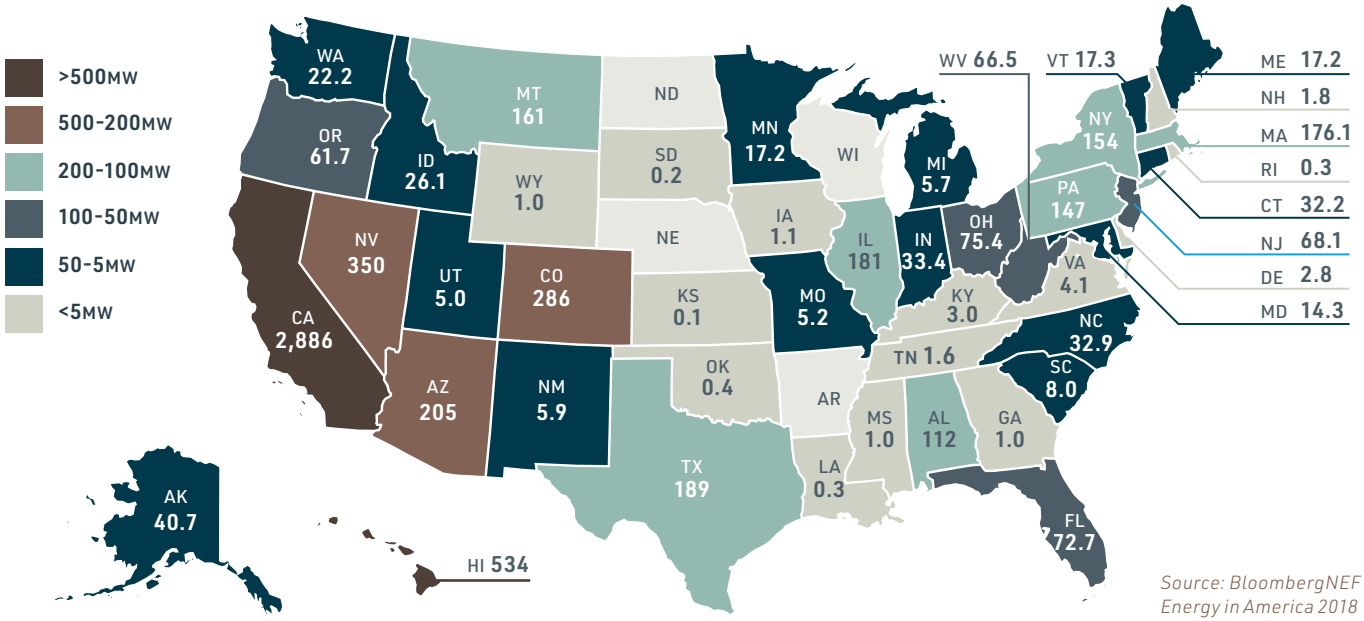
Source: Navigant Research



Across the United States, **a total of 5,752 MW** of energy storage capacity has been announced and commissioned.

Source: BloombergNEF Energy in America 2018

U.S. ENERGY STORAGE PROJECTS (announced and commissioned)



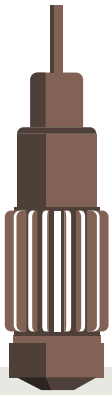
Source: BloombergNEF Energy in America 2018

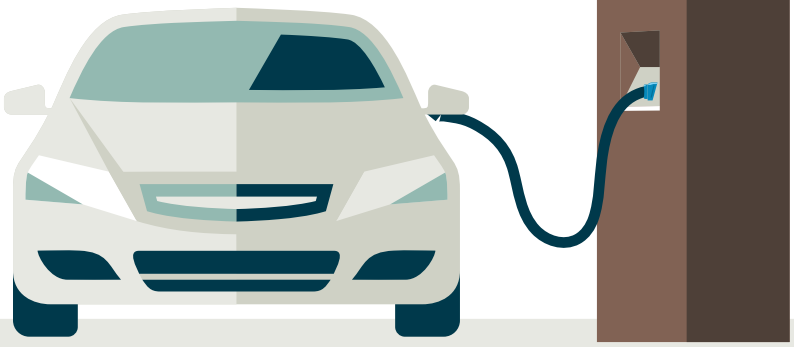
Copper in Electric Vehicles

Electric vehicles rely heavily on copper for the **motor coil that drives the engine**.

Additionally, the **cabling for charging stations** of electric vehicles will be another source of copper usage.

For example, BYD charging ports ranging from 3.3 kW to 200 kW contain between two to 17 pounds of copper. According to IDTechEx, BYD's total sale of chargers in 2016 used more than 295,000 lbs. of copper.





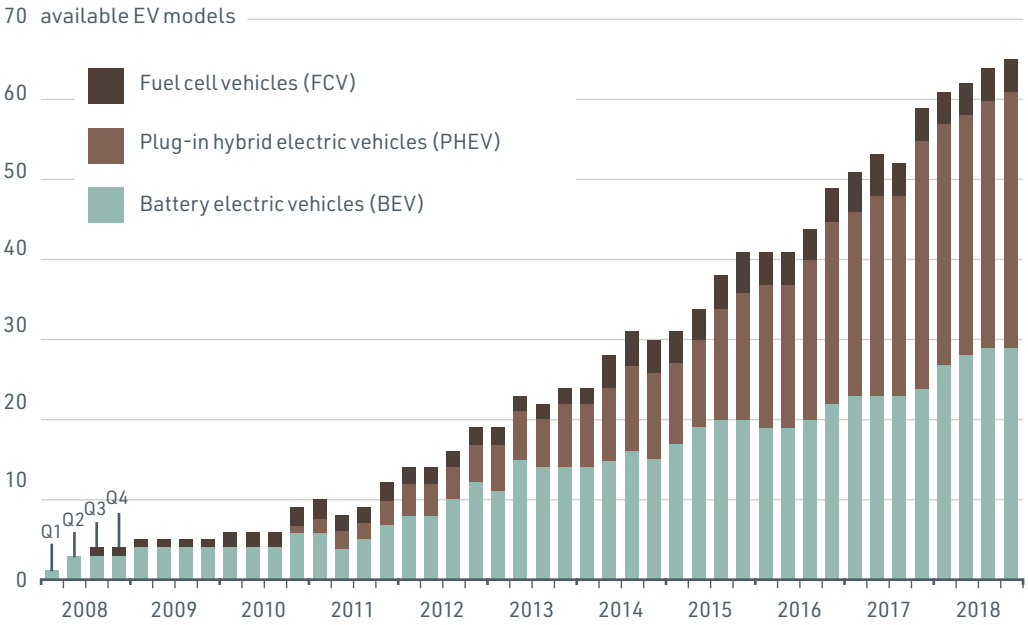
Source: Copper Development Association

COPPER CONTENT BY VEHICLE TYPE

Source: Reuters

*Electric vehicles are becoming more accessible as **more options enter the market**.*

EV MODEL AVAILABILITY IN NORTH AMERICA



By the fourth quarter of 2018, there were

4 FCVs

32 PHEVs

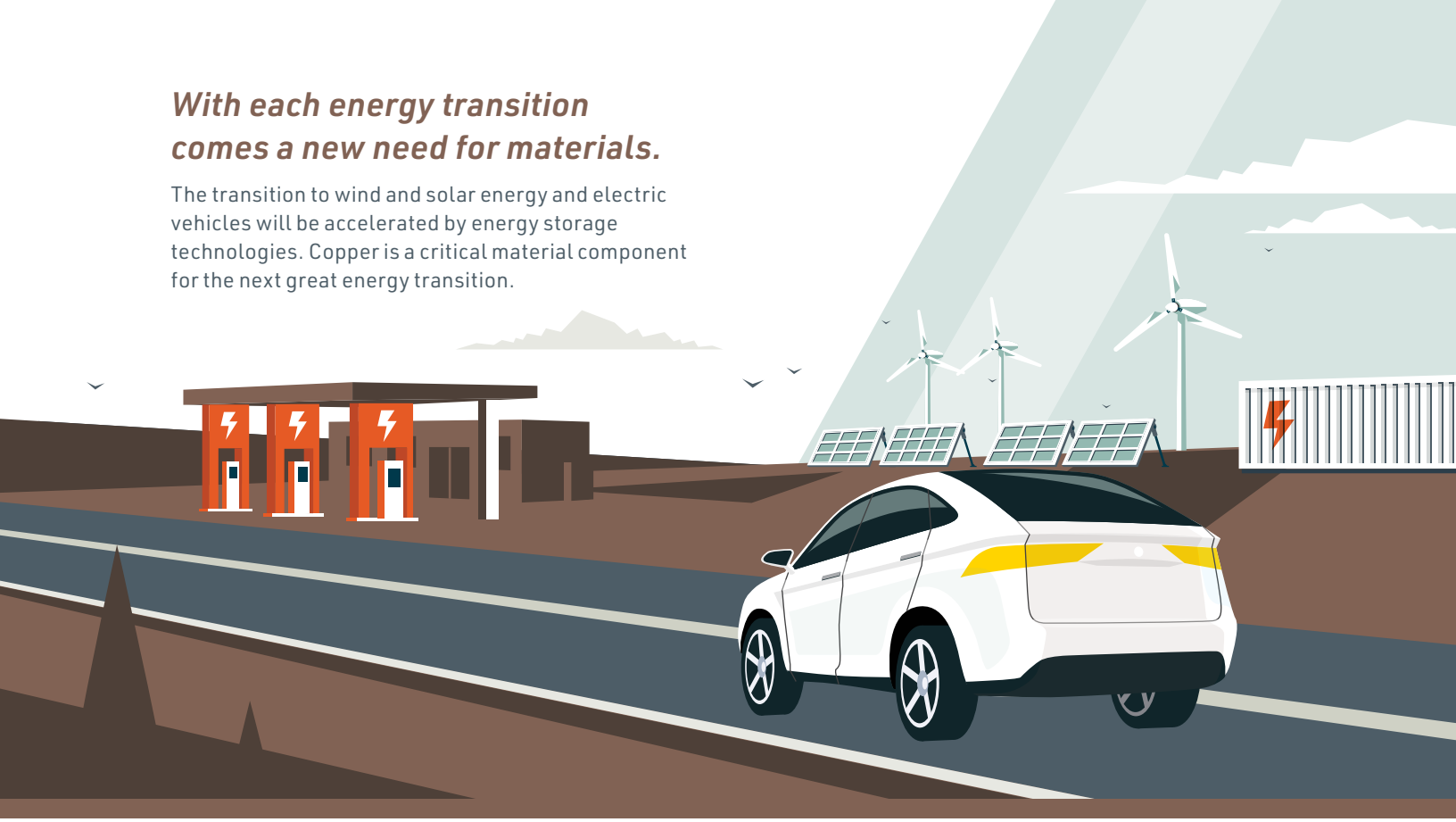
29 BEVs

available to consumers for purchase in North America.

Source: BloombergNEF Energy in America 2018

With each energy transition comes a new need for materials.

The transition to wind and solar energy and electric vehicles will be accelerated by energy storage technologies. Copper is a critical material component for the next great energy transition.



Copper Development Association Inc.

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Copper Development Association Inc.
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Copper Development Association Inc.
7918 Jones Branch Drive, Suite 300
McLean, VA 22102
Office: (202) 558-7625
Cell: (202) 674-9838
Skype: (212) 251-7238

Zolaikha Strong
Director – Energy Policy and Electrical Markets

zolaikha.strong@copperalliance.us
www.copper.org

WWW.COPPER.ORG

@copperenergy | @ThinkCopperUSA

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