

**DOCKETED**

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# Global Trends in Clean Power

BNEF presentation for California Energy  
Commission

Helen Kou

Senior Associate at BloombergNEF

May 12, 2023

# BNEF coverage

BloombergNEF

Strategies for a cleaner, more competitive future

## Commodities



Gas & LNG



Power



Oil



Carbon & offsets



Coal



Metals



Chemicals



Agriculture

## Sector transitions

### Clean power



Solar



Wind



Storage



Advanced nuclear



Power systems & networks

### Advanced transport



Electric vehicles



New mobility services & tech



Commercial transport



Aviation & shipping



Sustainable fuels

### Buildings & industry



Low-carbon heating & cooling



Circular economy



Green steel & aluminum



Sustainable plastics & chemicals



Low-carbon cement

### Agriculture / land



Agri-chemicals & biotechnology



Land & water management



Alternative proteins & food demand



Food waste management



Agricultural technology & supply chain

## Cross-cutting technologies



Industrial digitalization



Hydrogen



Bioenergy



Carbon capture, utilization, storage & removal (CCUSR)



Energy efficiency

## Sustainability



Corporate carbon & climate action



Regulation & reporting



Sustainable finance & ESG



Financial institution transition



Climate risk

Technology & Innovation

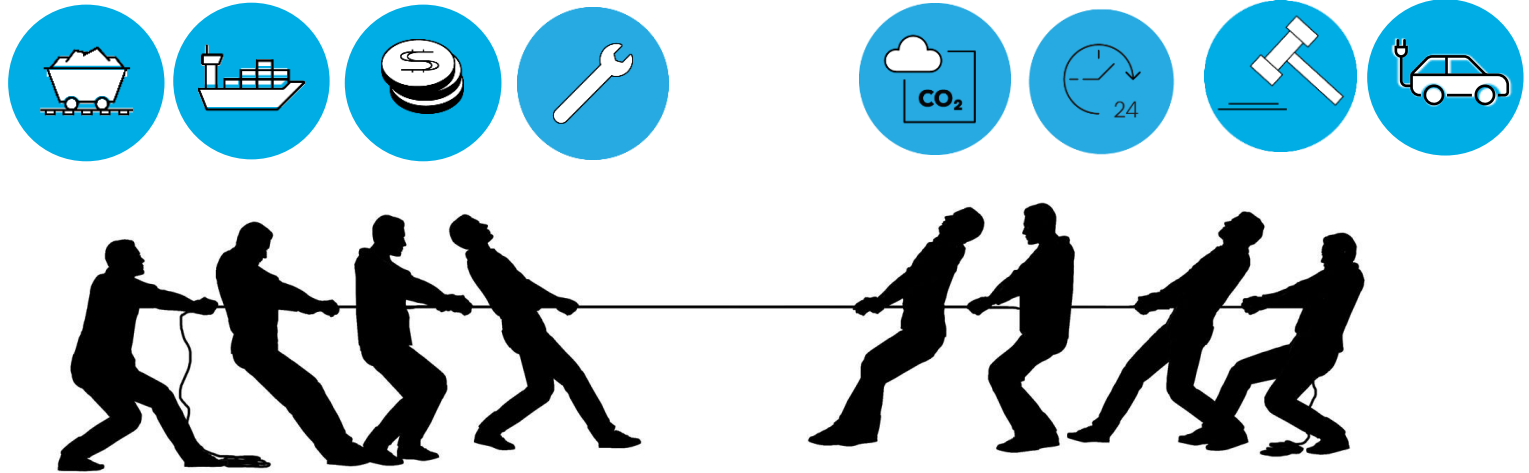
Forecasts & scenarios

Countries & policy

Finance & economics

Consumers

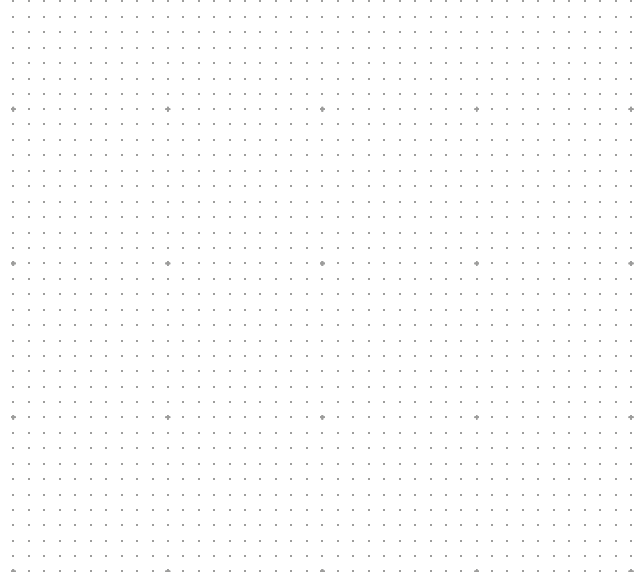
# Buffeted by competing forces, where does the momentum lie?



Source: Clipart-Library

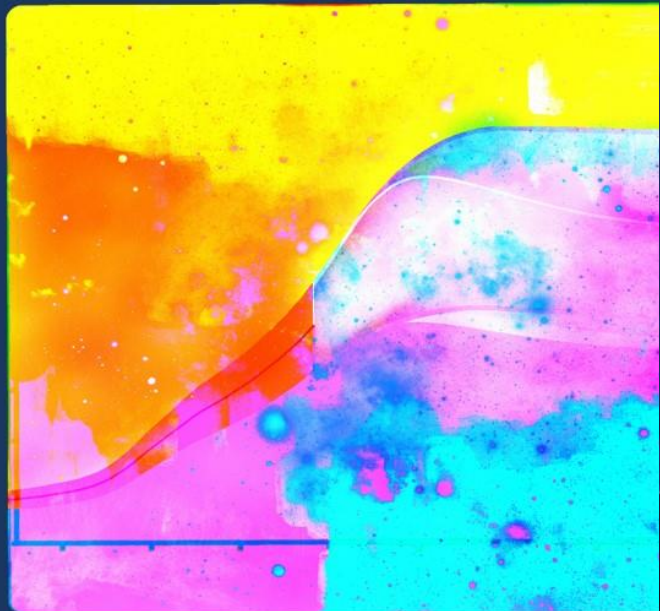
# Climate ambition has reached a high point

The past five years



# Global Warming of 1.5°C

An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.



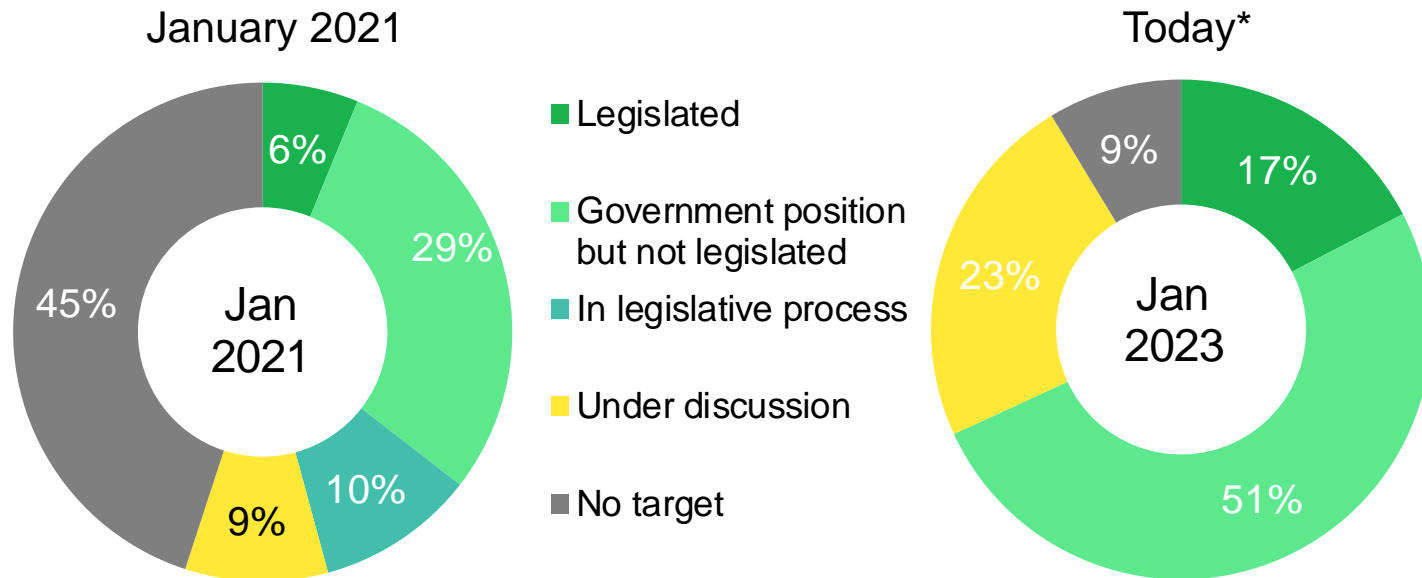
Source: Intergovernmental Panel on Climate Change, Bloomberg Mercury



Climate ambition has reached a high point

# Over 90% of global emissions are covered by government net-zero targets

Share of global emissions covered by regional, national and state-level net-zero targets

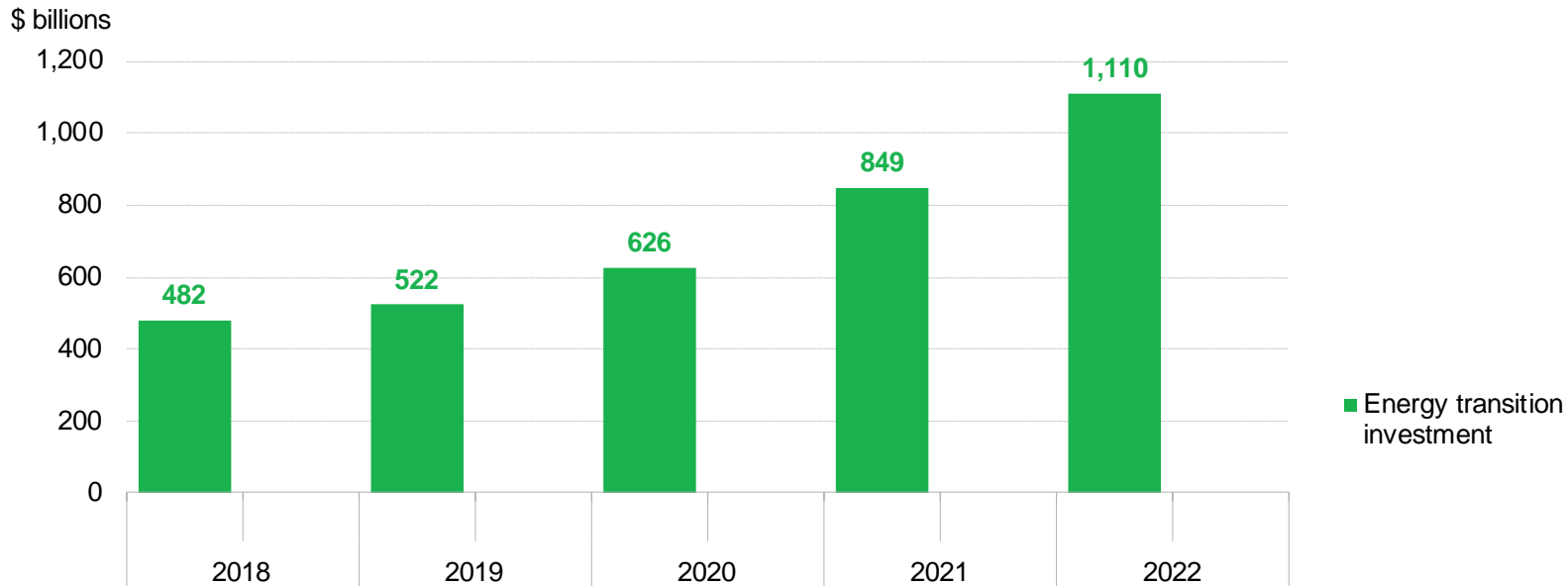


Source: BloombergNEF. Note: \*As of January 2023. Includes EU emission targets

Climate ambition has reached a high point

# Energy transition investment surged past \$1 trillion in 2022

## Energy transition and fossil fuel investment from 2018-2022



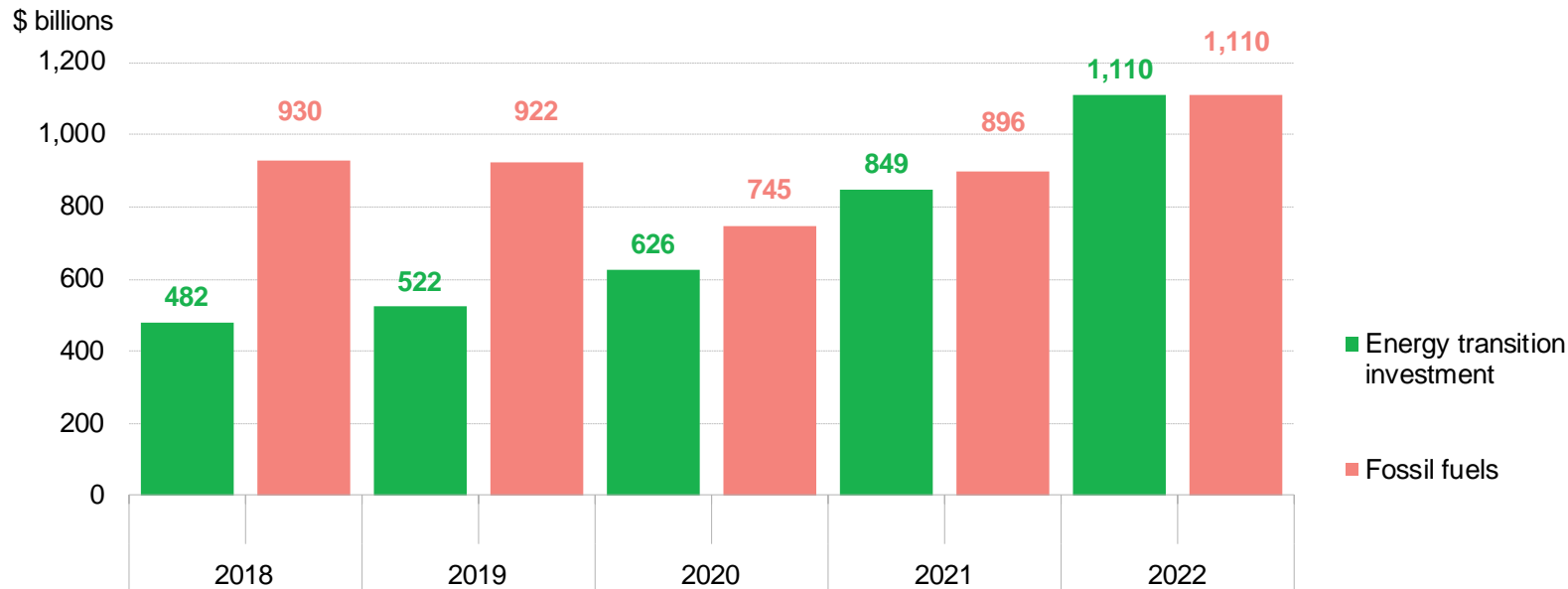
Source: BloombergNEF, IEA. Note: Fossil fuel investment values were derived from the IEA World Energy Investment 2022 report. 2022 fossil fuel investments are BNEF estimates, and include upstream, midstream, downstream sectors and unabated fossil power generation.



Climate ambition has reached a high point

# Energy transition investment on par with fossil fuels

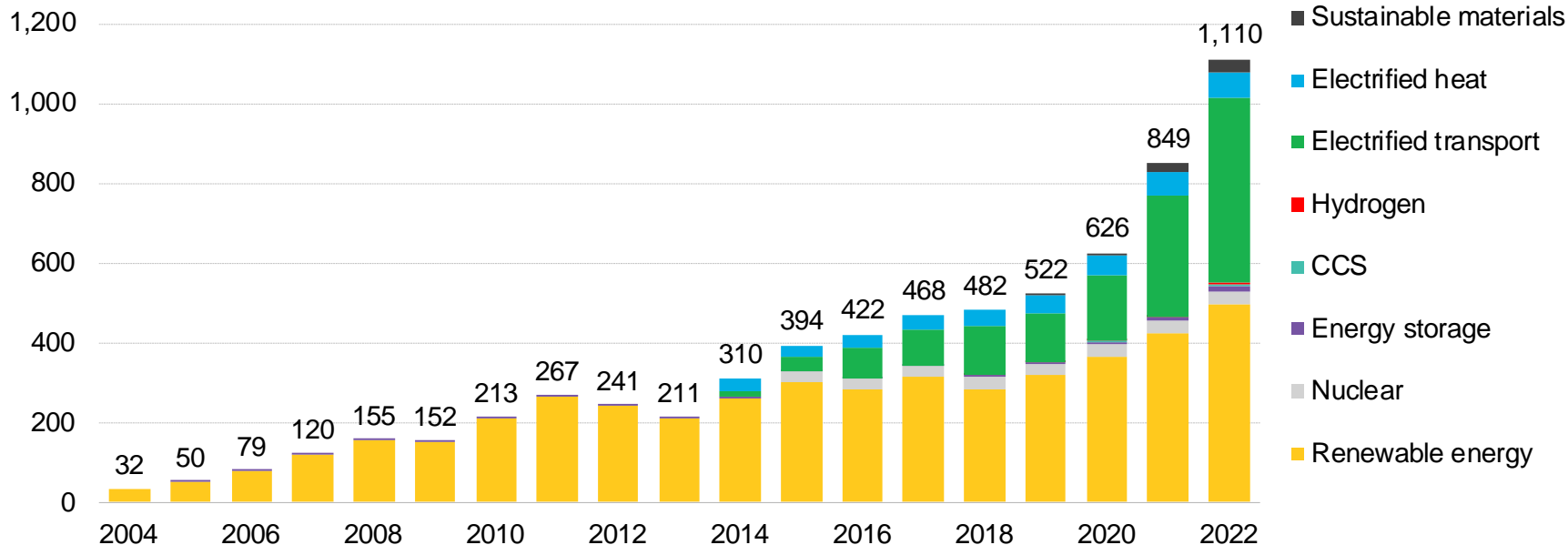
## Energy transition and fossil fuel investment from 2018-2022



Source: BloombergNEF, IEA. Note: Fossil fuel investment values were derived from the IEA World Energy Investment 2022 report. 2022 fossil fuel investments are BNEF estimates, and include upstream, midstream, downstream sectors and unabated fossil power generation.

## Global investment in energy transition by sector

\$ billion



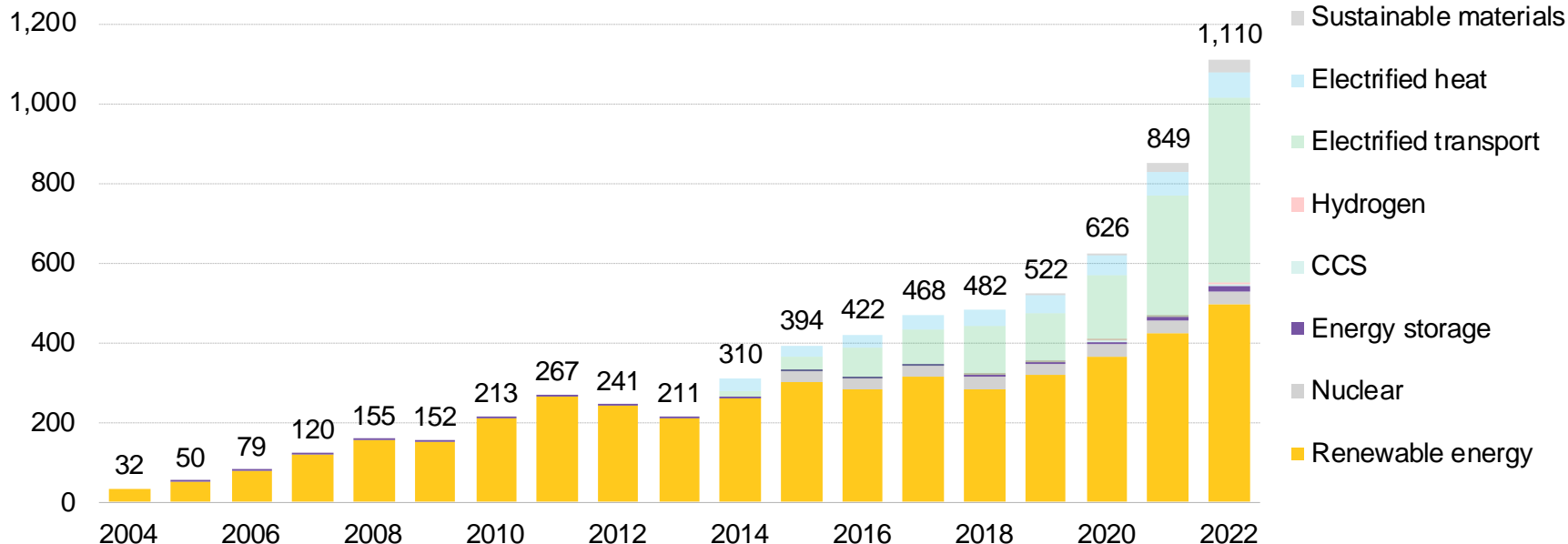
Source: BloombergNEF. Note: Start-years differ by sector but all sectors are present from 2019 onwards; see Appendix for more detail. Nuclear figures start in 2015.

Climate ambition has reached a high point

# Clean power investment remains strong

## Global investment in energy transition by sector

\$ billion



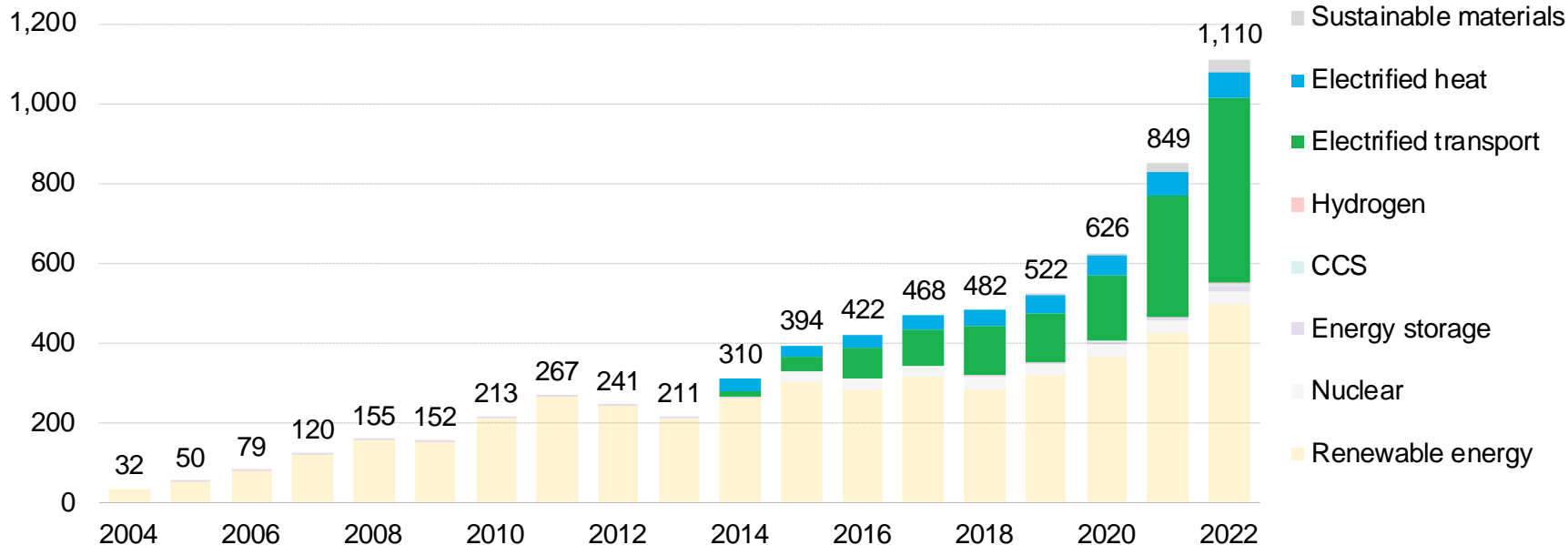
Source: BloombergNEF. Note: Start-years differ by sector but all sectors are present from 2019 onwards; see Appendix for more detail. Nuclear figures start in 2015.

Climate ambition has reached a high point

# Electrification is driving the acceleration

## Global investment in energy transition by sector

\$ billion

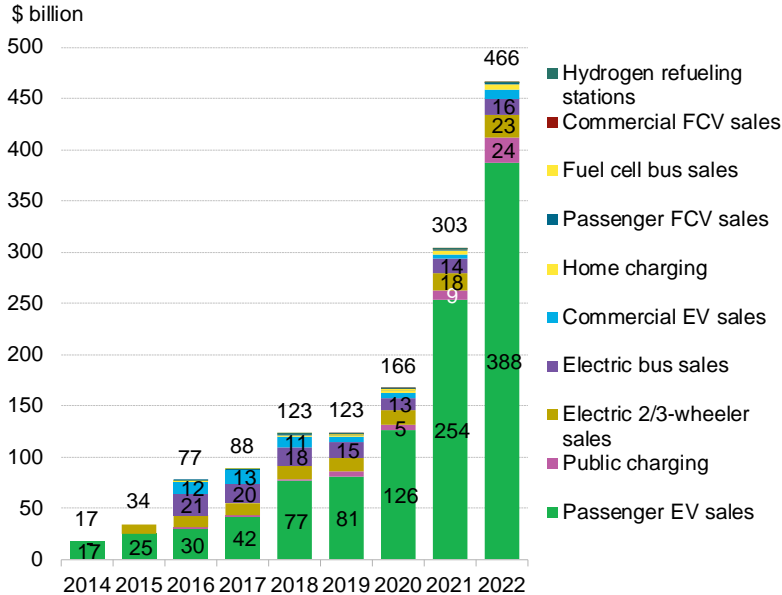


Source: BloombergNEF. Note: Start-years differ by sector but all sectors are present from 2019 onwards; see Appendix for more detail. Nuclear figures start in 2015.

Climate ambition has reached a high point

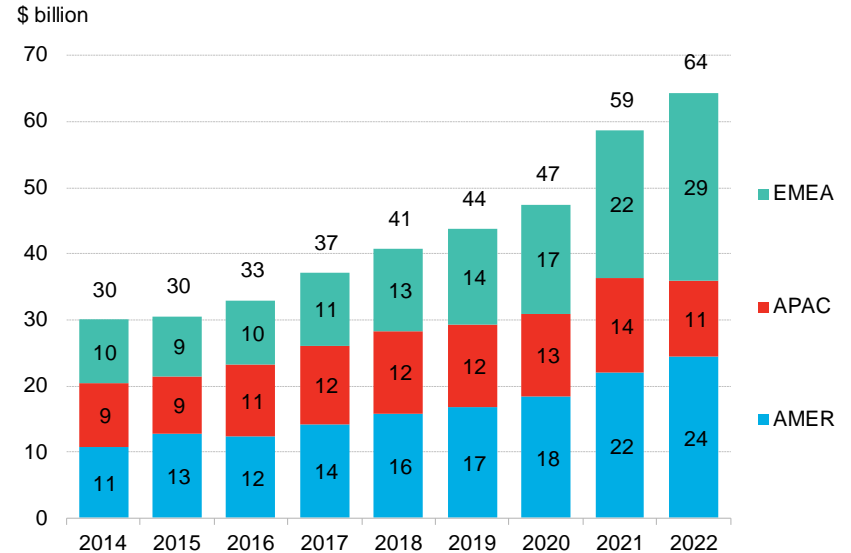
# Electrification is driving the acceleration

## Electrified transport spending by category



Source: BloombergNEF. Note: \* Electrified transport investment includes spending on vehicles and charging infrastructure. 2022 investment numbers are based on preliminary EV sales data. Totals include estimated vehicle prices. We do not capture private charging investment for commercial vehicles.

## Global investment in heat pumps by region



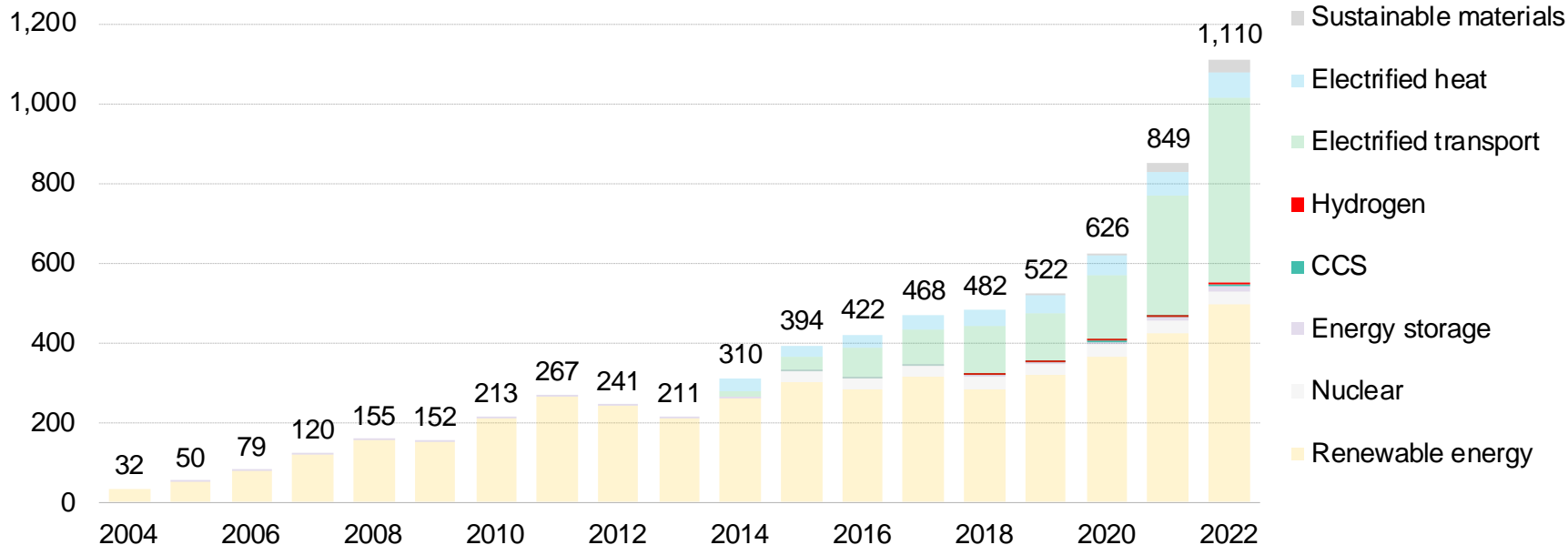
Source: BloombergNEF, European Heat Pump Association, US Air-Conditioning, Heating and Refrigeration Institute (AHRI), Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI), Qianzhan Industry Research Institute, Japan Refrigeration and Air Conditioning Association (JRAIA), consumer websites. Note: Investment calculated as sales multiplied by the average cost for equipment and installation for a typical single-family home. Currency conversion based on average exchange rate over the course of a year.

Climate ambition has reached a high point

# Less-mature technologies are starting to scale

## Global investment in energy transition by sector

\$ billion

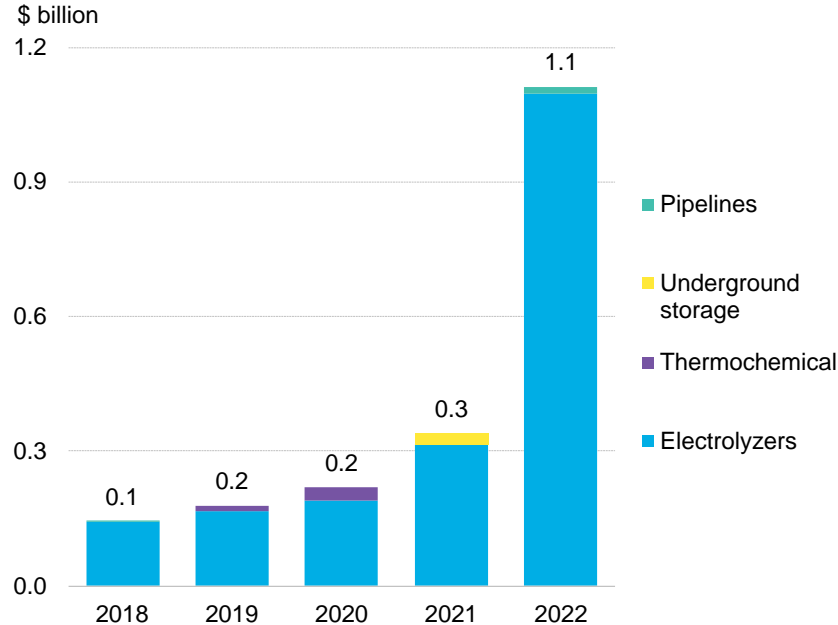


Source: BloombergNEF. Note: Start-years differ by sector but all sectors are present from 2019 onwards; see Appendix for more detail. Nuclear figures start in 2015.

Climate ambition has reached a high point

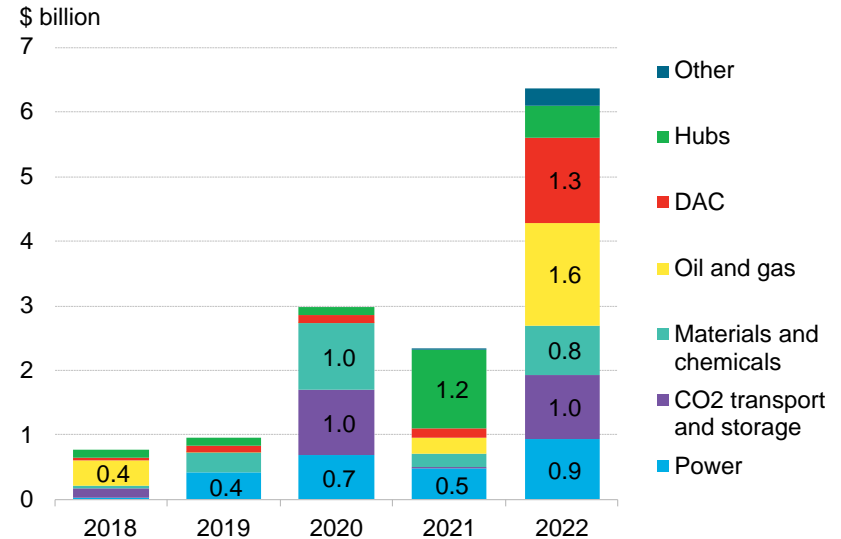
# Less-mature technologies are starting to scale

## Hydrogen investment by category



Source: BloombergNEF

## Carbon capture and storage investment by sector



Source: BloombergNEF. Note: includes corporate R&D to develop first phases of specific CCS projects, government R&D, venture capital funding for direct air capture plants and point source technologies.

# A net-zero future is still within reach

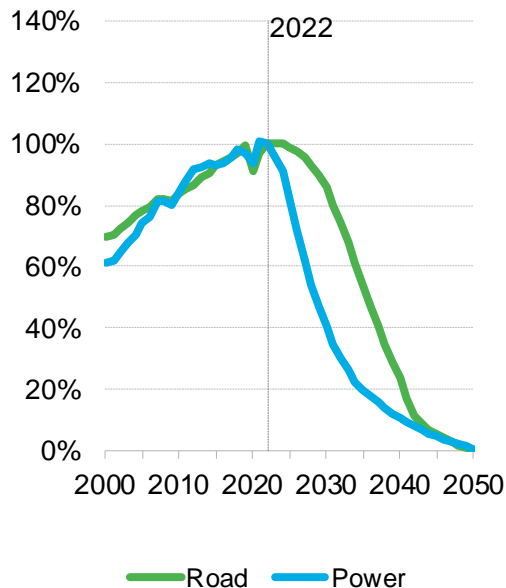
Electrification, clean power and new technologies are key



A net-zero future is still within reach

# Net Zero Scenario: A sector-led approach to carbon budgets based on known technology solutions

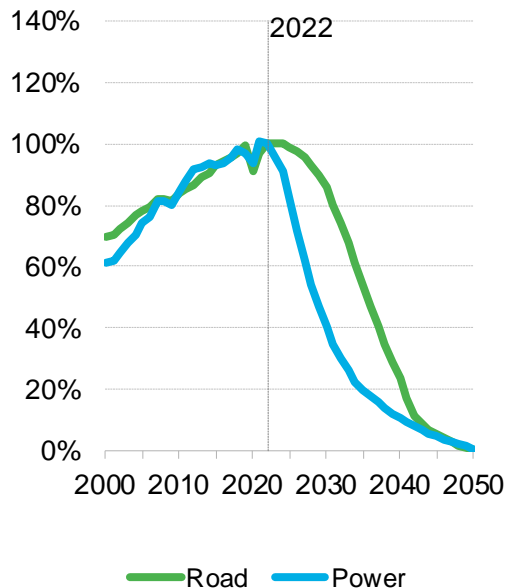
## Cost-competitive pathway



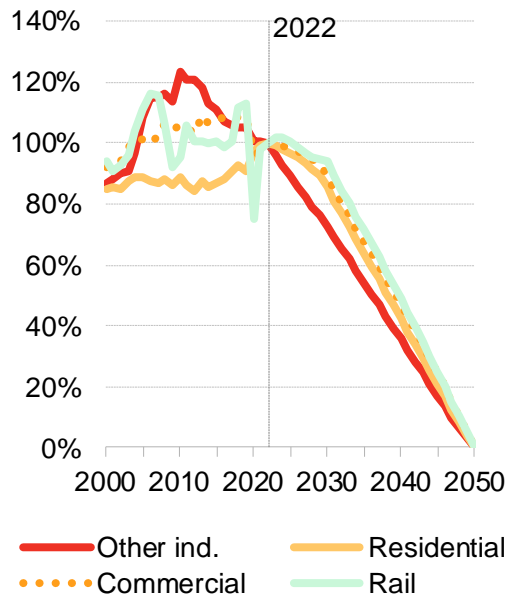
Source: BloombergNEF. Note: Charts rebased to 2022 = 100.

# Net Zero Scenario: A sector-led approach to carbon budgets based on known technology solutions

## Cost-competitive pathway



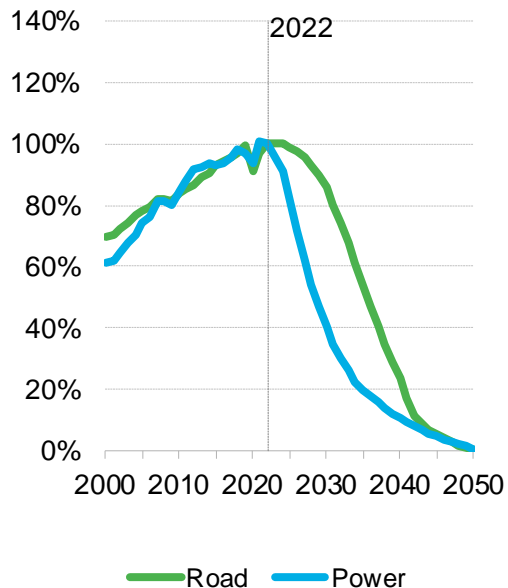
## Known technologies



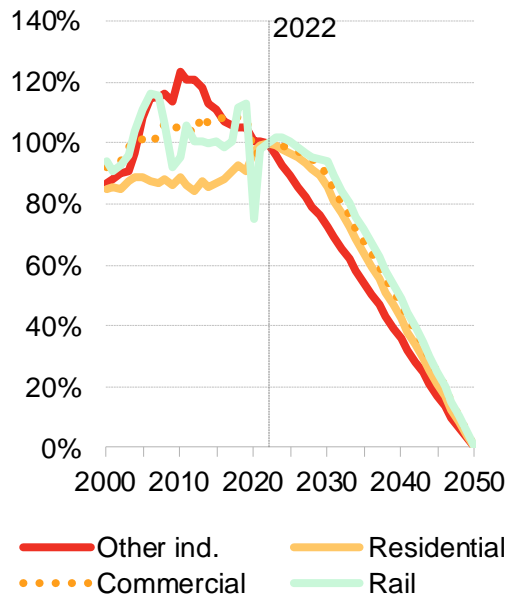
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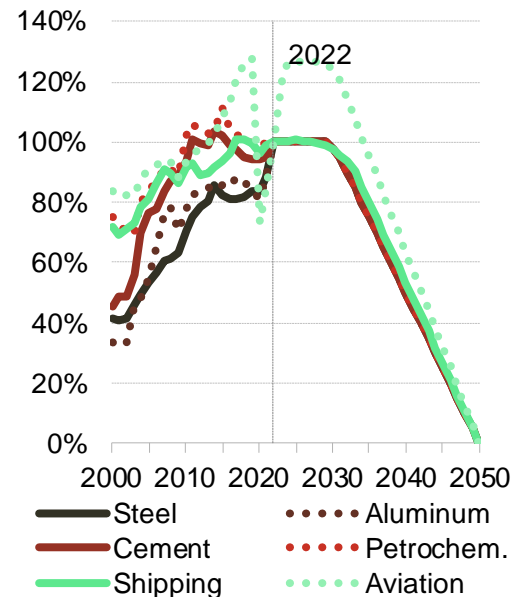
## Cost-competitive pathway



## Known technologies



## Hard-to-abate

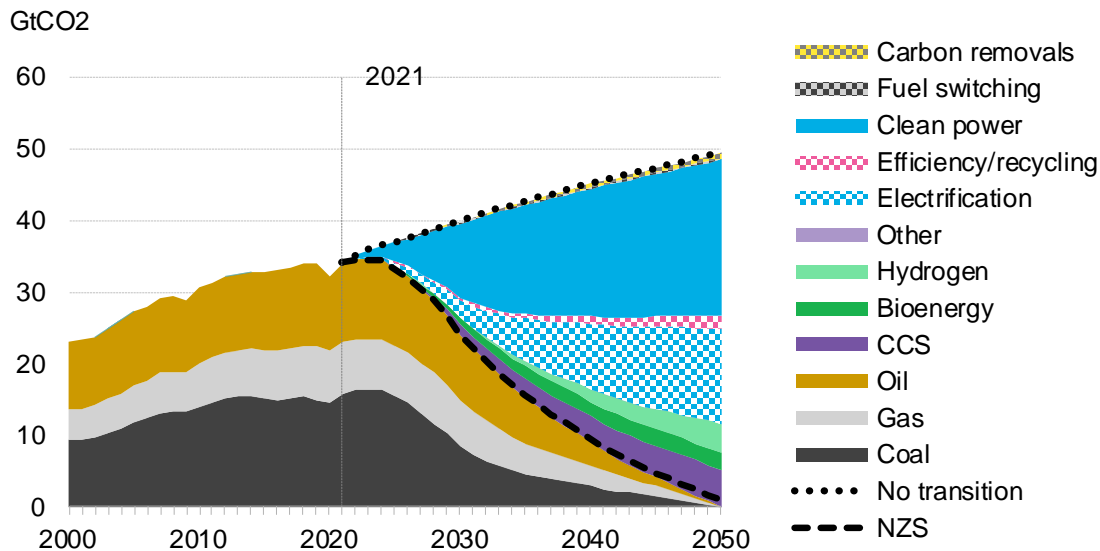


Source: BloombergNEF. Note: Charts rebased to 2022 = 100.

A net-zero future is still within reach

# Clean power, electrification, new technologies are key for net zero

## CO2 emissions reductions-Net Zero Scenario (NZS) versus a No Transition scenario (ETS)



Source: BloombergNEF New Energy Outlook 2022 Net-Zero Scenario.

**4x** Rise in carbon capture and storage, 2050 vs 2030

**5x** Rise in final hydrogen consumption, 2050 vs 2022

**7x** Rise in primary clean power production, 2050 vs 2022

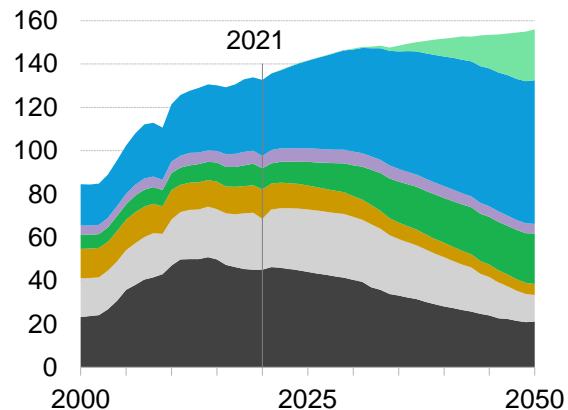
A net-zero future is still within reach

# How we make things and consume energy will have to change...

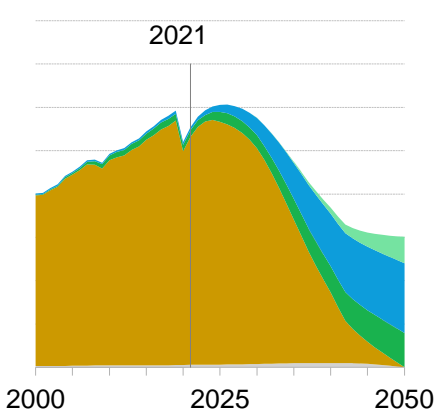
## Final energy mix by sector under the Net Zero Scenario

### Industry

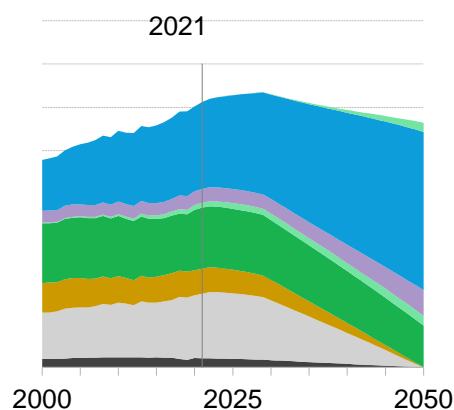
Exajoules



### Transport



### Buildings



- Hydrogen
- Electricity
- Heat
- Renewables
- Bioenergy
- Oil
- Gas
- Coal

Source: BloombergNEF.

A net-zero future is still within reach

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A net-zero future is still within reach

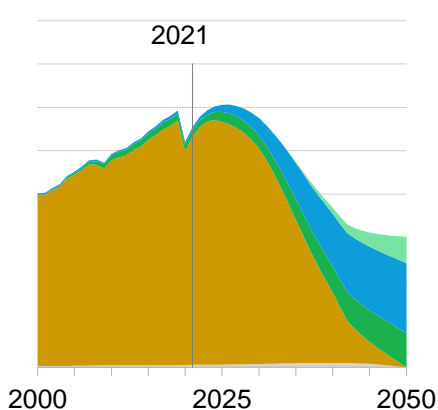
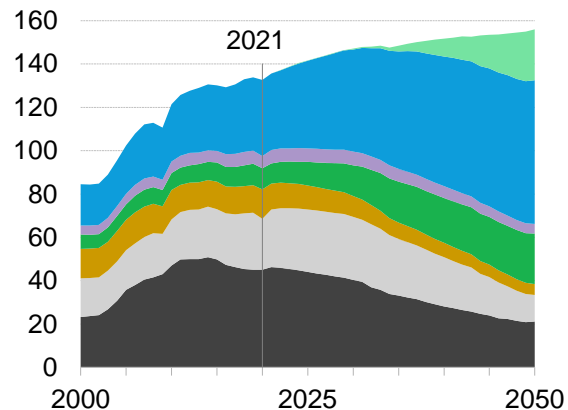
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Exajoules



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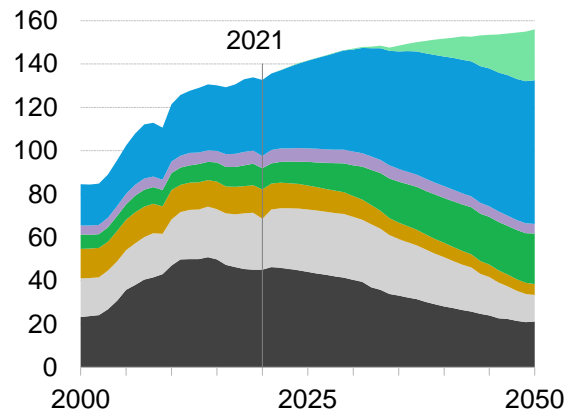
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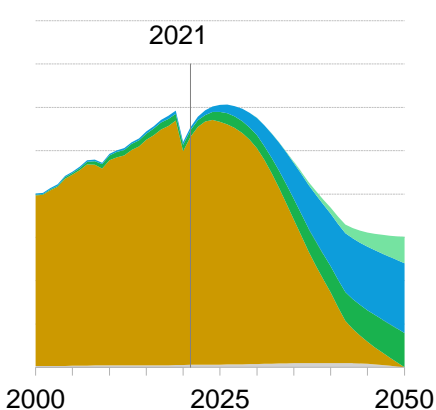
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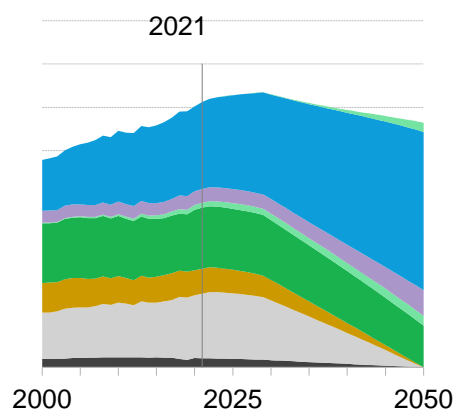
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Source: BloombergNEF.



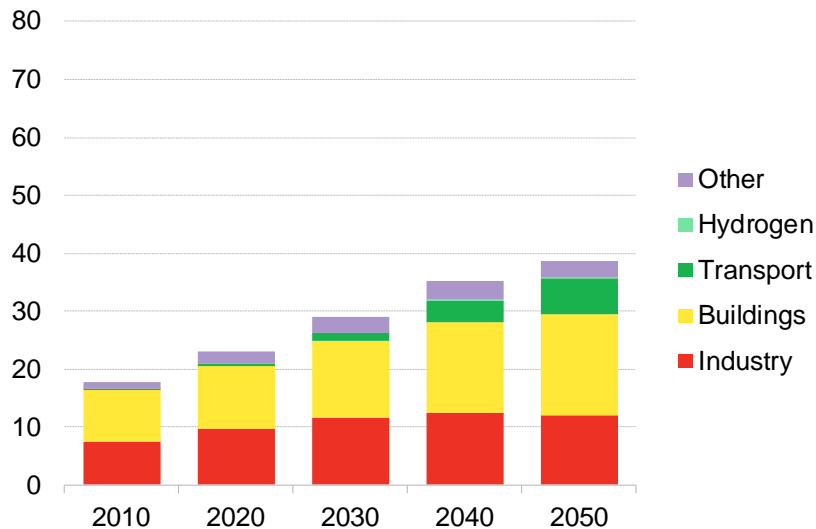
A net-zero future is still within reach

# Electrification will triple the size of the power system in the Net Zero Scenario

## Electricity demand:

### Economic Transition Scenario

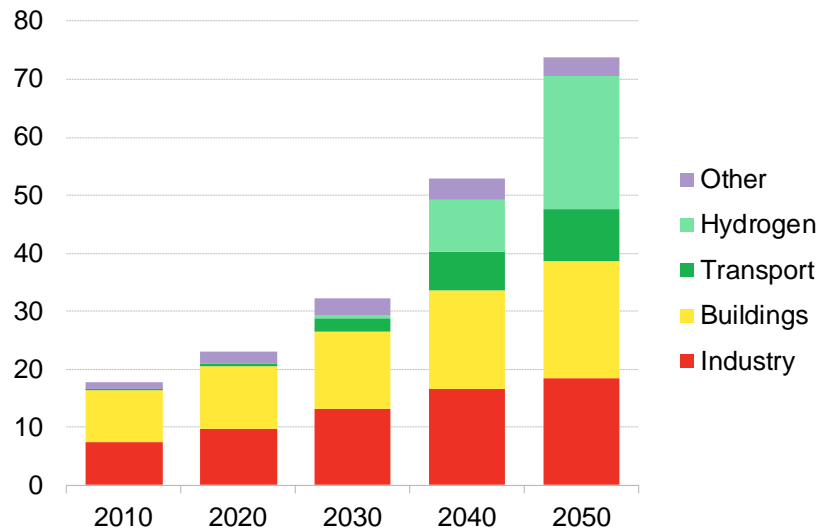
1,000TWh



Source: BloombergNEF. Note: Electricity demand net of generation losses.

### Net Zero Scenario

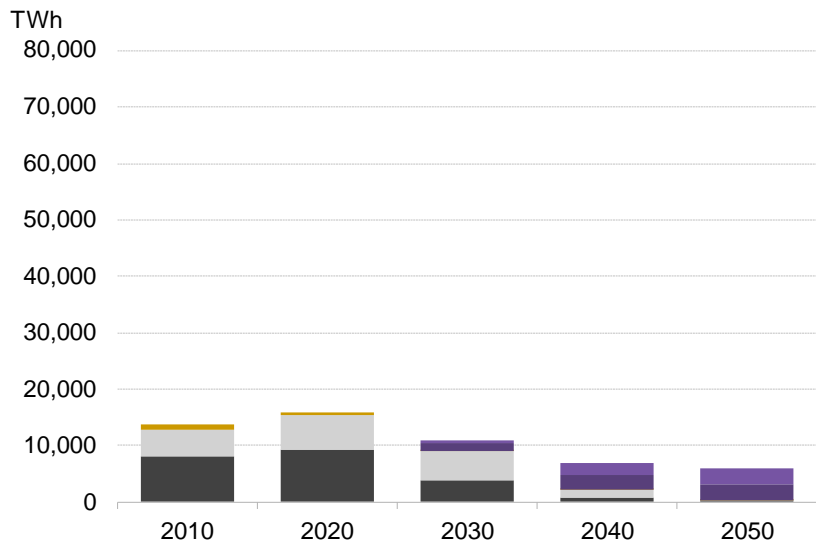
1,000 TWh



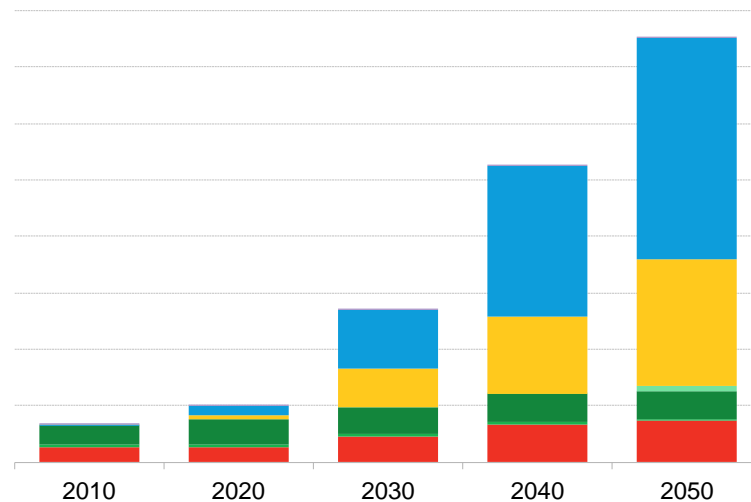
Source: BloombergNEF. Note: Electricity demand net of generation losses.

# ...and the move to clean power will be supercharged

## Fossil fuel generation under the NZS



## Low-carbon generation under the NZS



Other Wind Solar Other renewables Bioenergy Nuclear Hydrogen Gas with CCS Coal with CCS Oil Gas Coal

Source: BloombergNEF New Energy Outlook 2022 Net Zero Scenario

Source: BloombergNEF New Energy Outlook 2022 Net Zero Scenario

# Scaling up clean power deployment remains a challenging

Will government targets outstrip reality?

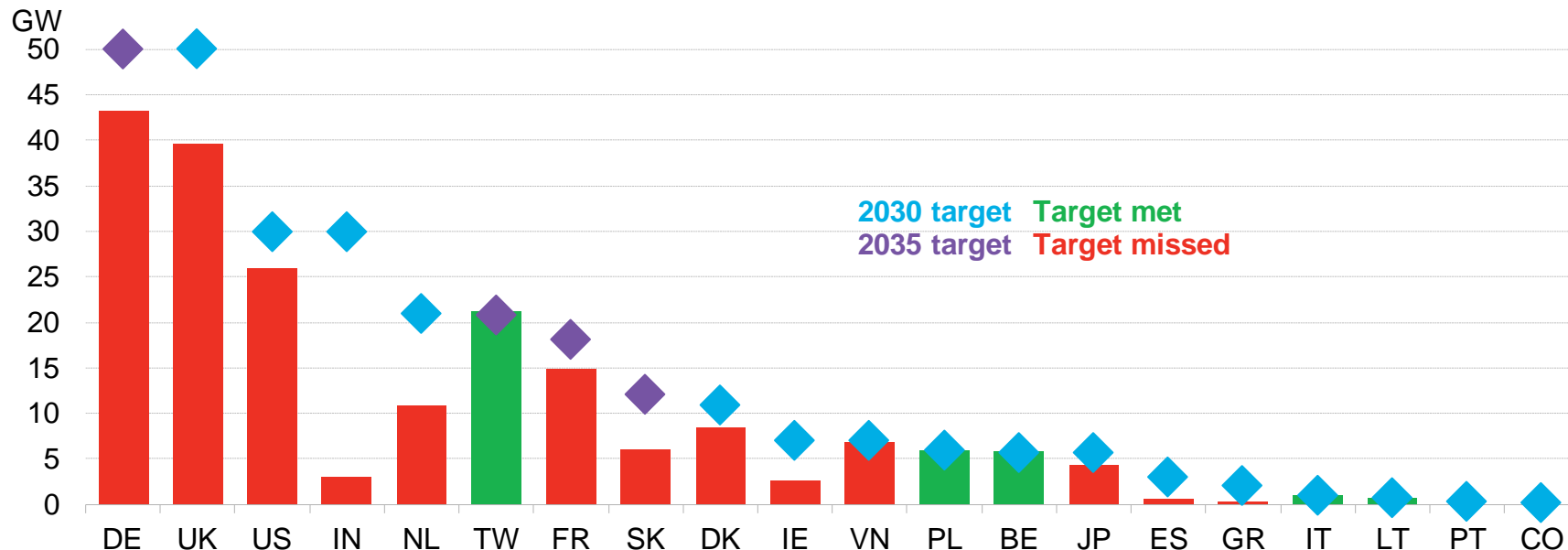
# Ambitious targets



Source: Bloomberg Mercury

# Ambitious targets, ambiguous outlook

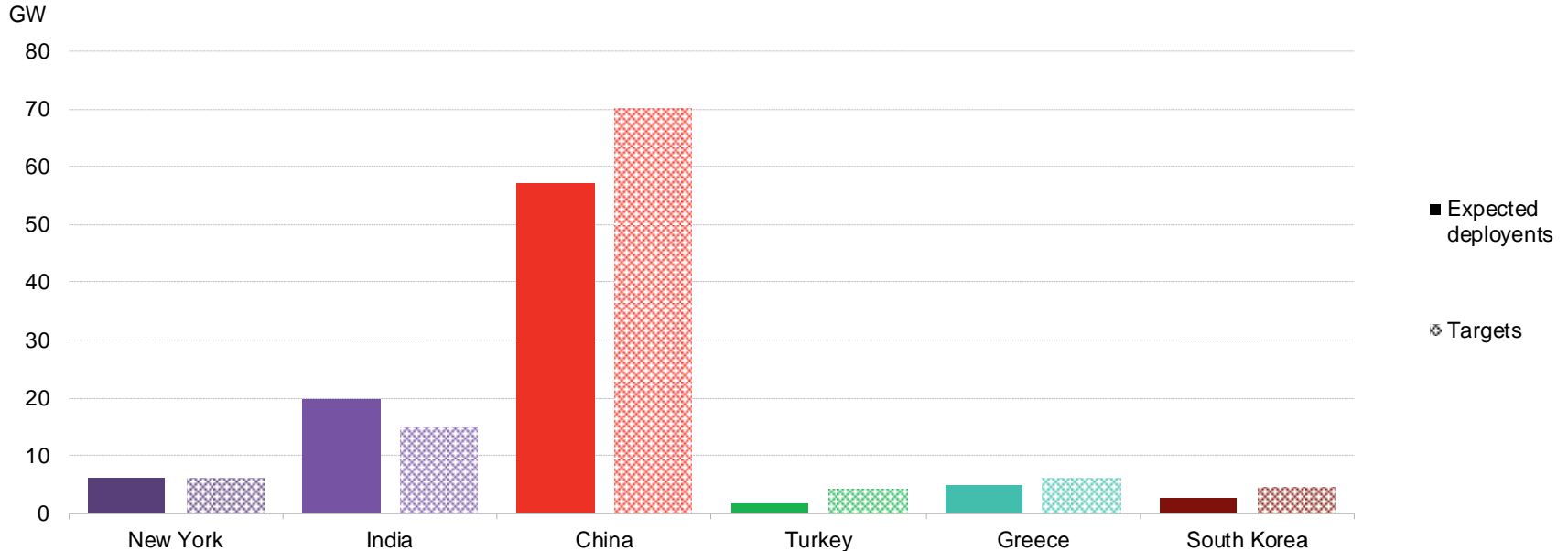
## Wind turbine capacity forecast vs government goals



Source: BloombergNEF. Note: Bars show BloombergNEF forecast. Considers announced country-level installation targets for the latest target date within the horizon of BNEF's forecast. We assume the lower end of Colombia's (CO) 0.2 to 1GW-by-2030 target in the chart. Vietnam's offshore wind target has not been finalized and excludes nearshore projects while we include them in our forecast. Norway has an offshore wind target of 30GW by 2040; we forecast that the country will install 4.6GW by 2035.

# Ambitious targets, ambiguous outlook

## Energy storage targets versus expected deployments by target date



Source: BloombergNEF Note: India's target is estimated, based off our assumptions on expected renewable generation by 2030. Turkey's deployment is calculated based off its 2035 7.5GW target.

# Three challenges to overcome for greater renewable energy deployment



**Supply chains**  
(eg, vessels)



**Rising costs**  
(eg, equipment, labor rates,  
debt, interest rates)



**Grids and infrastructure**  
(eg, interconnection  
and capacity)

# Three challenges to overcome for greater renewable energy deployment



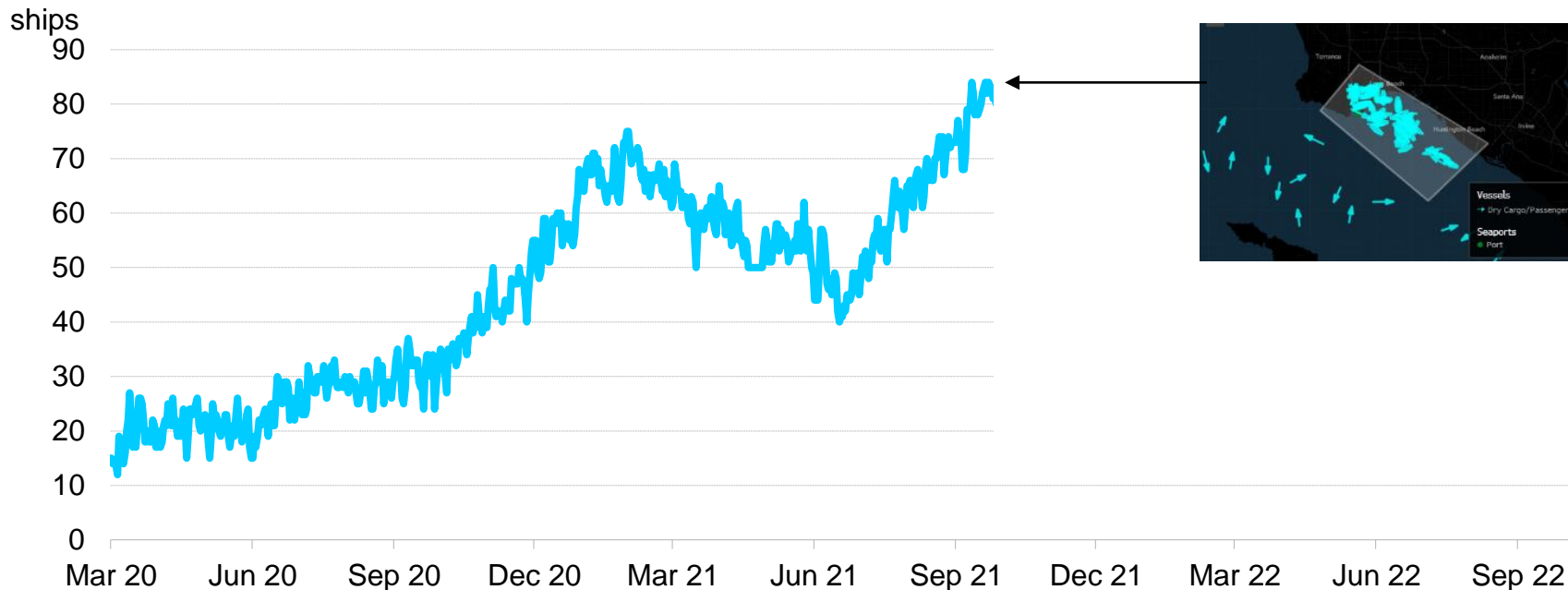
**Supply chains**  
(eg, vessels)

Source: *Wikimedia Commons, BloombergNEF*



# Ports spent much of the pandemic congested

## Number of ships at the port of Los Angeles



Source: Bloomberg {WCIDSHLA Index}

# Port congestion has been easing throughout 2022, removing another bottleneck

## Number of ships at the port of Los Angeles



Source: Bloomberg {WCIDSHLA Index}

# Three challenges to overcome for greater renewable energy deployment



## Supply chains

(eg, vessels)



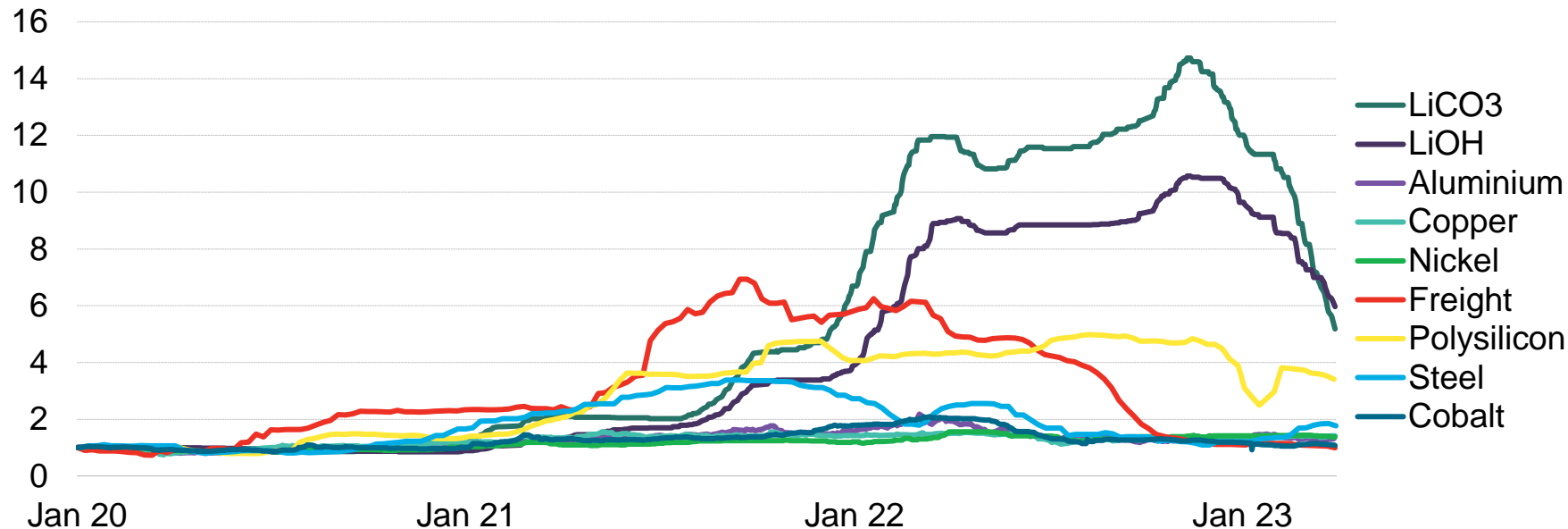
## Rising costs

(eg, equipment, labor rates, debt, interest rates)

Source: *Wikimedia Commons, BloombergNEF*

# Rising material spot prices raised clean energy equipment costs

Price movements of key components, rebased to one in January 2020

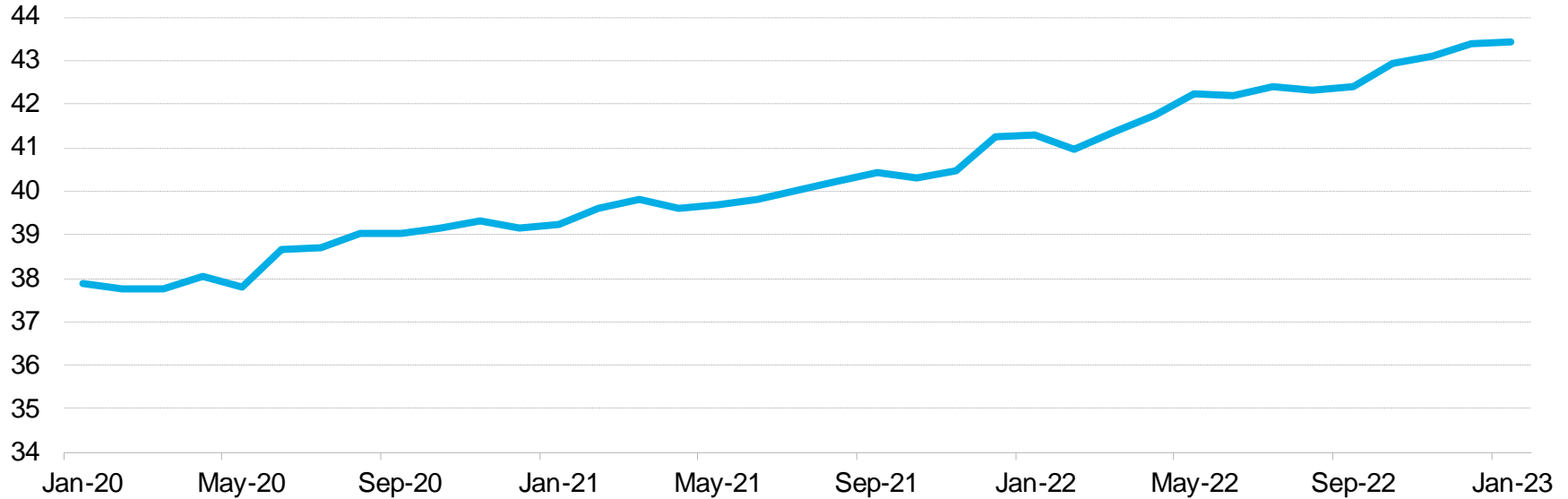


Source: BloombergNEF, Bloomberg Terminal. Note: Data rebased to 1 on earliest available date in January 2020. Shanghai-LA freight rates used, steel reflects North America costs, while aluminum and copper are China prices – more details as well as Bloomberg Terminal tickers available in the Excel attached to the report. Run {97<GO>} on Terminal or click here to access the Excel.

# But it is not just raw materials, labor costs have increased as well

## Average hourly earnings of utility production employee

\$earnings/hour

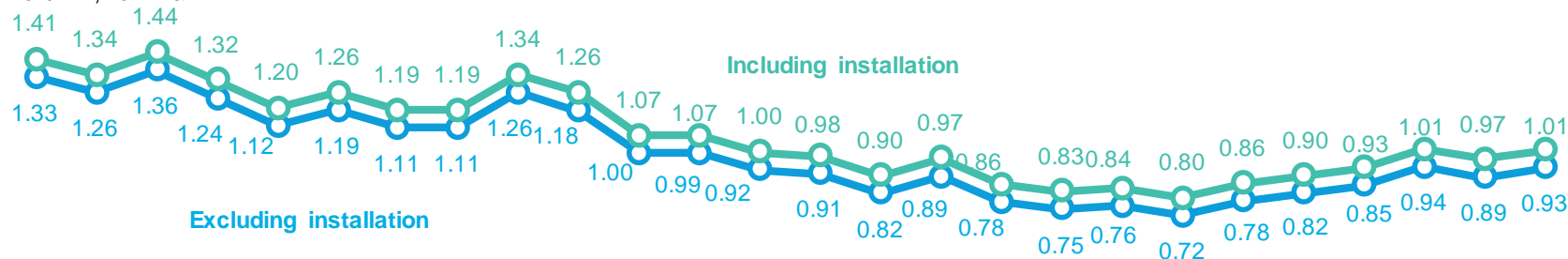


Source: [US Bureau of Labor Statistics](#), BloombergNEF

# Onshore wind turbine prices have risen 30% from pre-pandemic levels

## Onshore wind turbine contract prices

\$million/MW, nominal



1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	
2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022

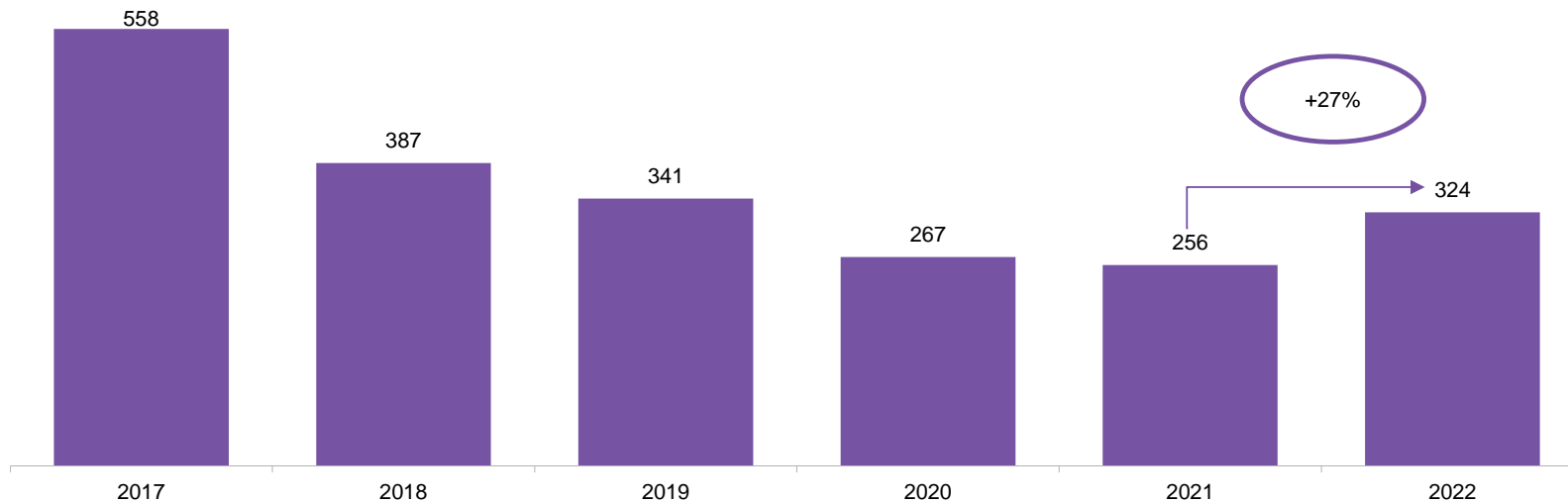
Signing date

Source: BloombergNEF. Note: U.S. turbine supply contracts typically excludes installation and commissioning cost. European and Latin American turbine supply contracts typically include installation and commissioning costs.

# Energy storage system costs rose 27% from 2021-2020

## Historical prices for turnkey energy storage systems of four-hour duration

Real 2022 \$/kWh, usable

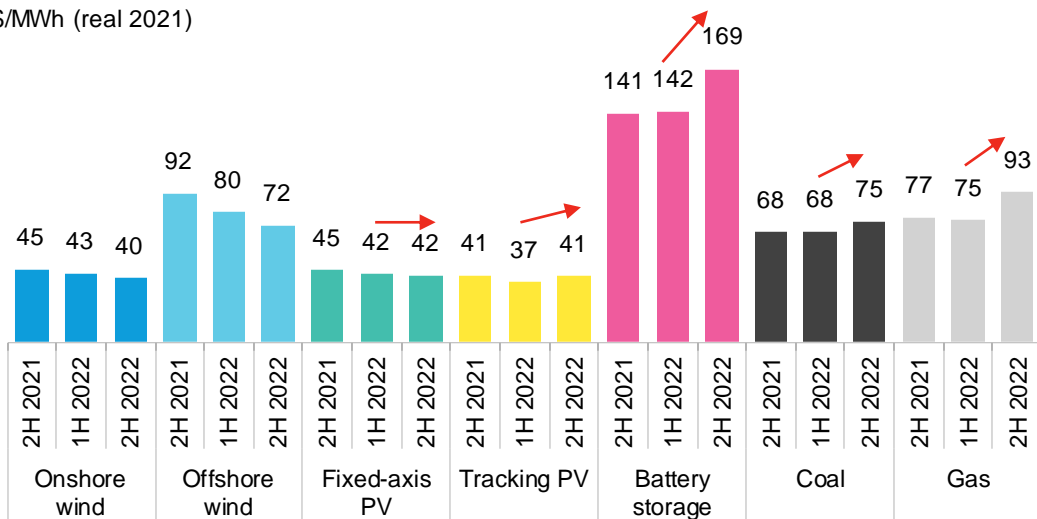


Source: BloombergNEF. Note: Historical prices have been adjusted using June 2021 to June 2022 inflation rates based on US Consumer Price Index (CPI).

# LCOEs are rising for the first time in history, driven by supply chains, inflation and pricier debt

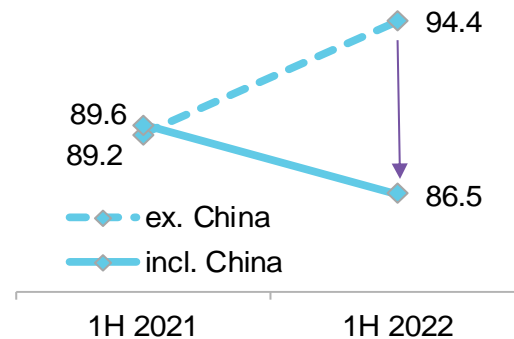
## Change in global LCOEs, 2H 2021 through 1H 2022

\$/MWh (real 2021)



## Impact of China on offshore wind LCOE benchmark

\$/MWh (nominal)



Source: BloombergNEF. Note: The global benchmarks are country-weighted levelized cost of electricity (LCOE) averages using the latest annual capacity additions. Offshore wind includes offshore transmission costs. LCOEs do not include subsidies or tax credits.



# Three challenges to overcome for greater renewable energy deployment



**Supply chains**  
(eg, vessels)



**Rising costs**  
(eg, equipment, labor rates,  
debt, interest rates)

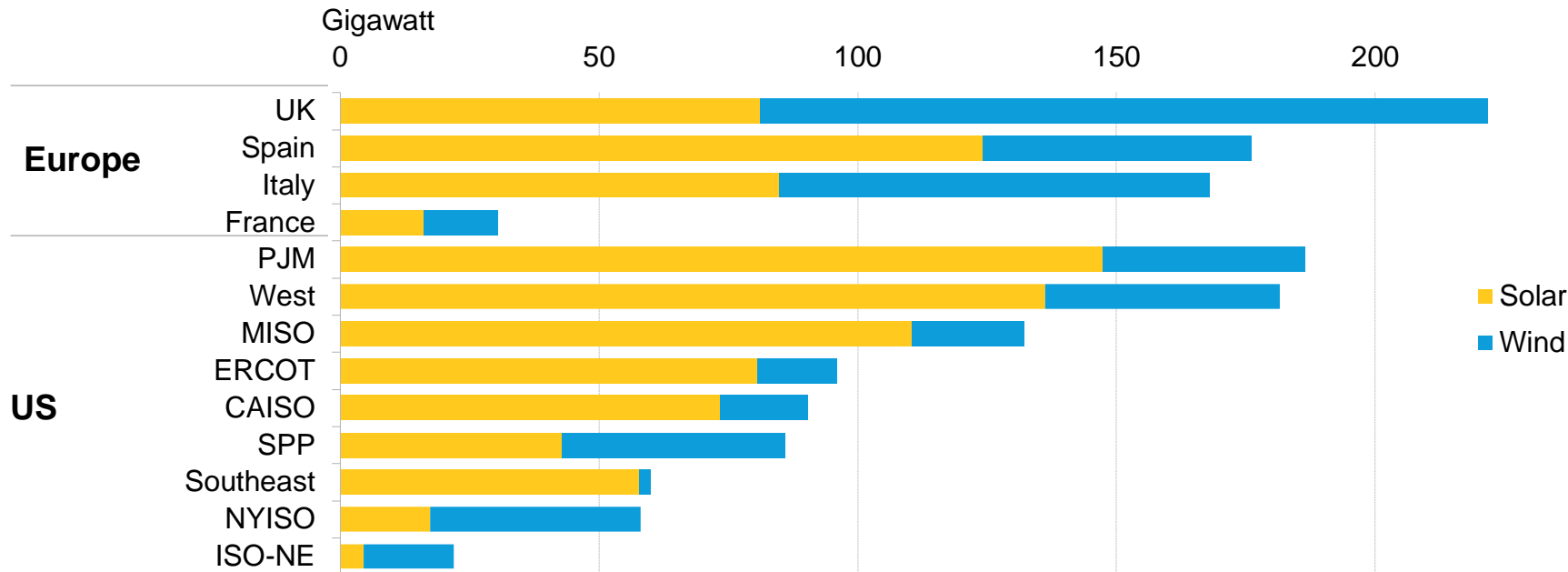


**Grids and infrastructure**  
(eg, interconnection  
and capacity)

Source: *Wikimedia Commons, BloombergNEF*

# Renewable deployment is stifled by grid connection queues

## Grid connections queues for wind and solar in select countries

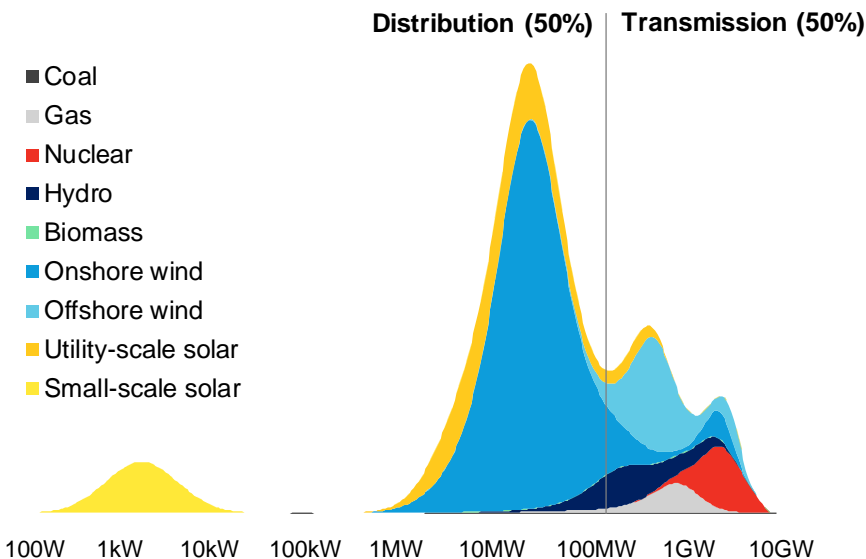


Source: BloombergNEF, Lawrence Berkeley National Lab, National Grid, Electricity Northwest, Northern Powergrid, SSE Networks, Scottish Power Energy Networks, UK Power Networks, Terna, Red Electrica, French Ministry of Ecological Transition. Note: UK data is as of December 2022, Spain as of August 2022, Italy as of end-2021, France as of October 2022 and the US as of end-2021. Battery hybrid projects are included. Wind includes both onshore and offshore sites.

A net-zero future is still within reach

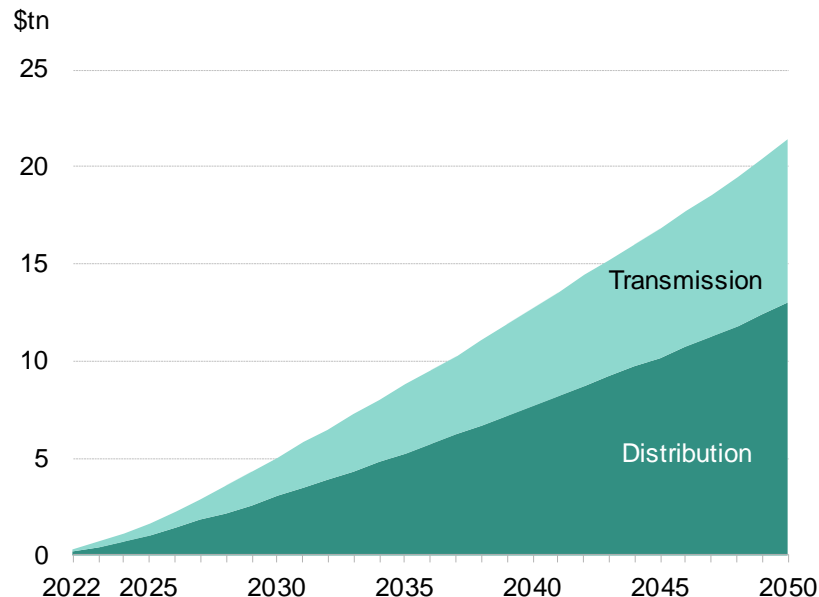
# The grid becomes more decentralized, needs \$21 trillion of investments

## Distribution of generation mix by plant size in 2030, Europe, NZS



Source: BloombergNEF. Note: gas includes some hydrogen.

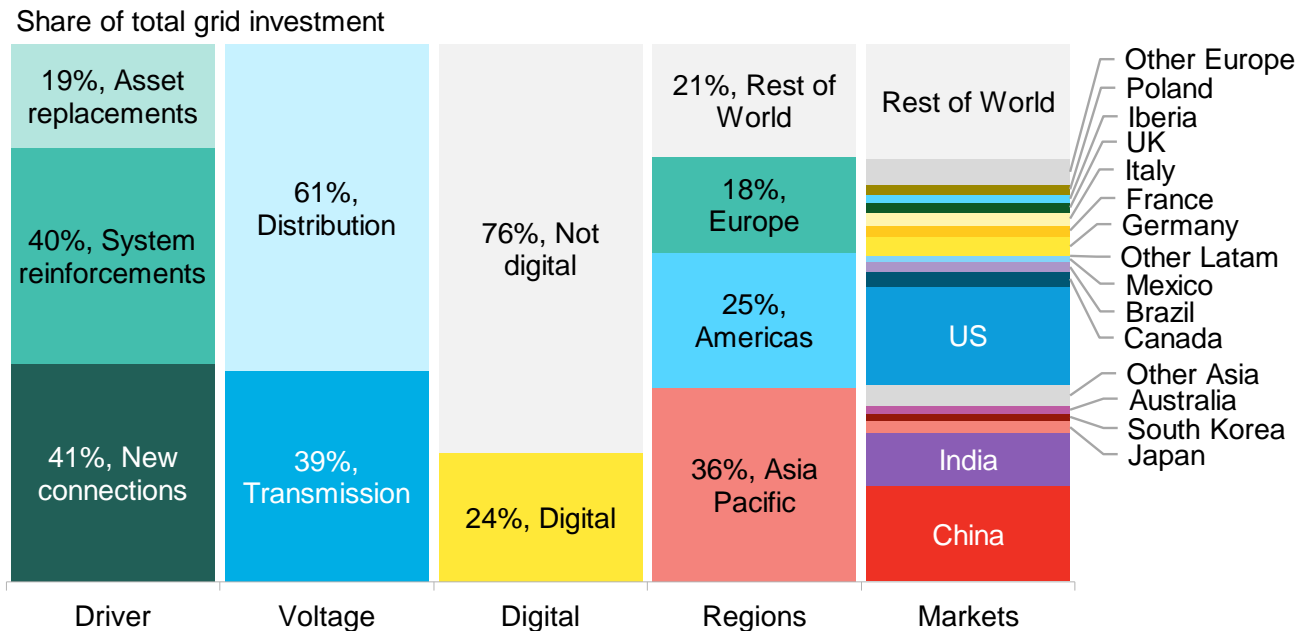
## Cumulative global grid investment, NZS



Source: BloombergNEF.

# At least \$21.4 trillion needs to be invested in electricity grids by 2050

## Breakdown of global grid investment in net zero scenario 2022-2050

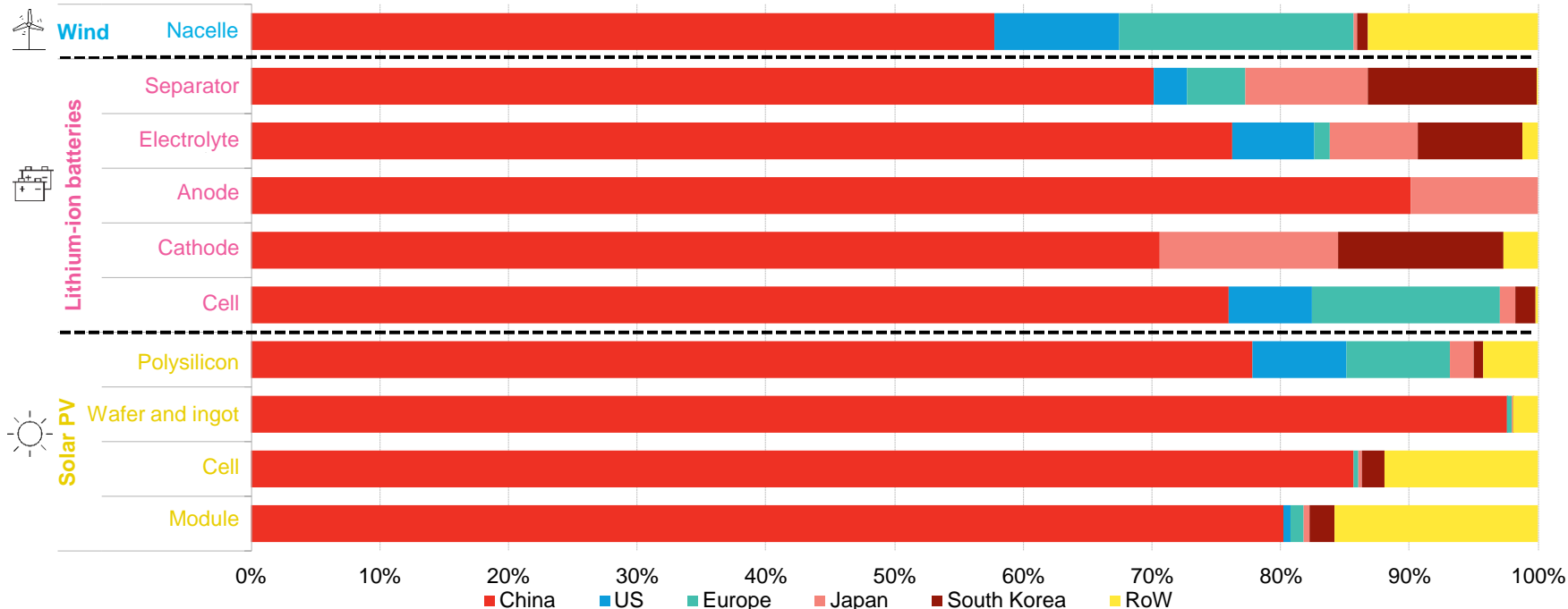


Source: BloombergNEF

# Entering a new era for the energy transition

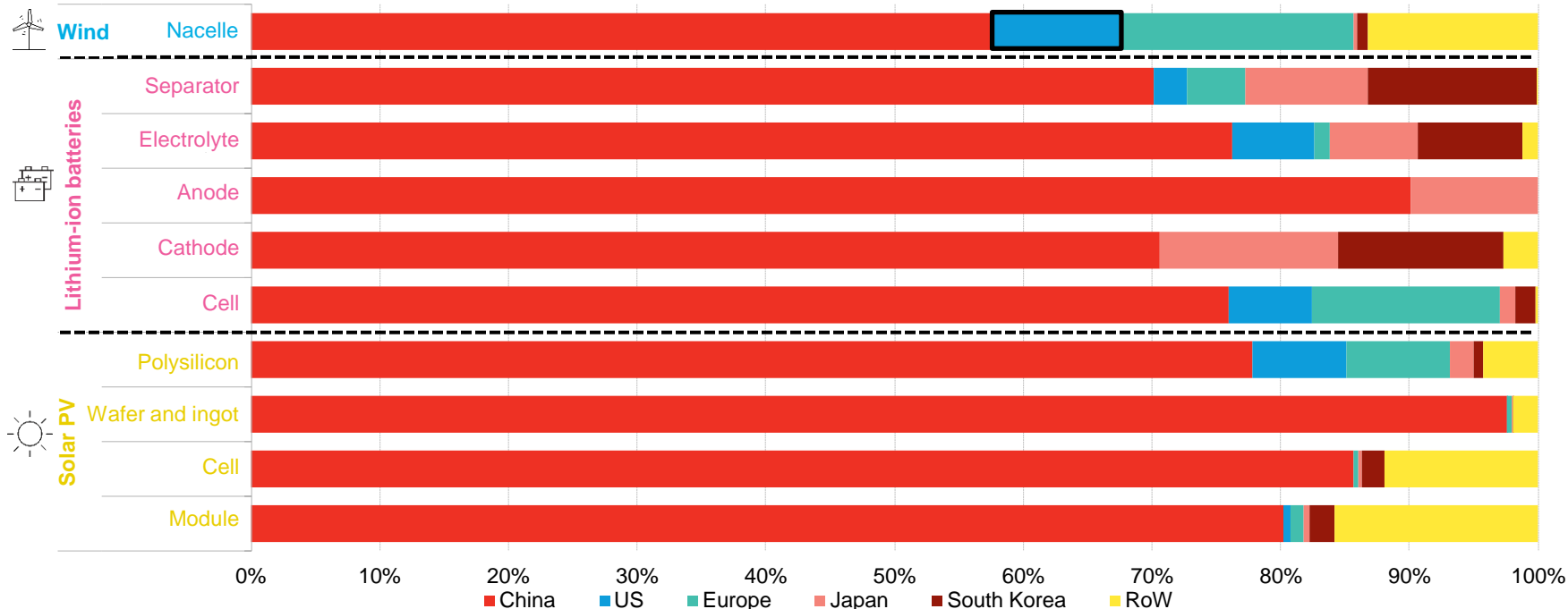
Countries vie for clean power dominance, system volatility rises

# China dominates clean energy manufacturing capacity



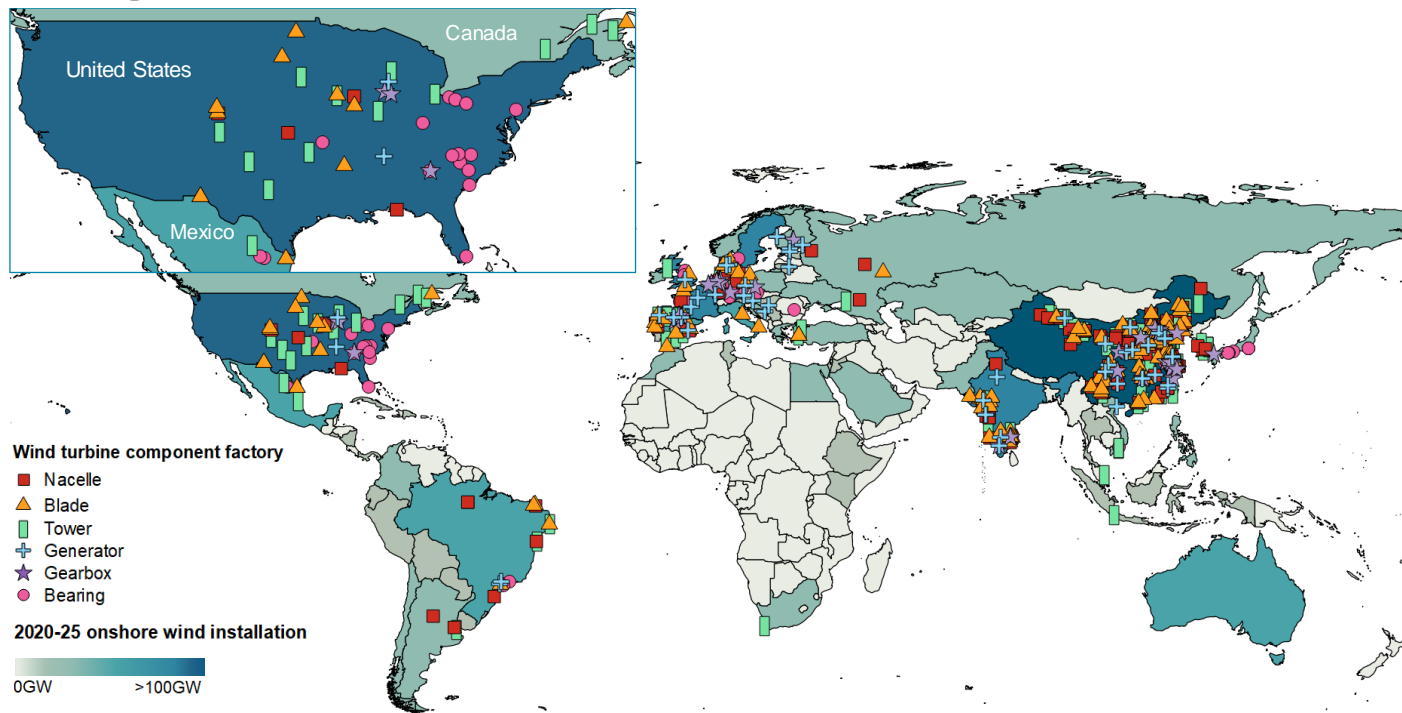
Source: BloombergNEF. Note: By factory location. PV, hydrogen and battery components expressed in MW, MWh, m<sup>2</sup> or tons. Nickel is the class 1 variety, and lithium is in lithium carbonate equivalent. H<sub>2</sub> is hydrogen. Data as of October 2022 except electrolyzers (which refer to 2021) and nacelle data (which are for 2020).

# China dominates clean energy manufacturing capacity



Source: BloombergNEF. Note: By factory location. PV, hydrogen and battery components expressed in MW, MWh, m<sup>2</sup> or tons. Nickel is the class 1 variety, and lithium is in lithium carbonate equivalent. H<sub>2</sub> is hydrogen. Data as of October 2022 except electrolyzers (which refer to 2021) and nacelle data (which are for 2020).

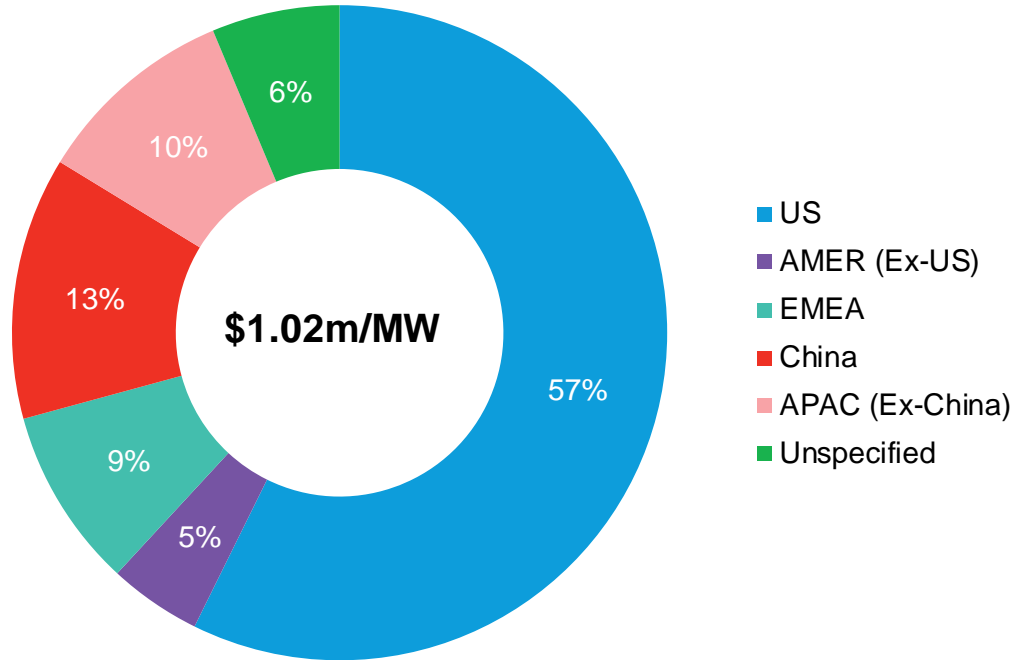
# The US is a major wind supply chain hub, alongside China, Europe and India



Source: BloombergNEF. Note: Data as of September 25, 2020. Includes only operational factories.



# US-manufactured components account for most of a wind turbine's value



Source: BloombergNEF, USITC, LBNL. Note: Includes blade, tower, gearbox, generator, converter, bearing, yaw and pitch, and balance of nacelle. APAC = Asia Pacific. EMEA = Europe, Middle East and Africa. AMER = Americas.

Entering a new era for the energy transition

# International competition is ratcheting

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Politics QuickTake

## Why Biden's Green Subsidies Have US Allies Fuming



The USA and European Union

By [Bryce Baschuk](#)  
January 18, 2023 at 4:13:36 PM GMT  
From **Bloomberg QuickTake**

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## Climate Policy Has Become Central in the Fight for Global Power

- Major economies are creating incentives for green investment
- Russia's war in Ukraine has made Europe's shift more urgent



Margrethe Vestager, competition commissioner of the European Commission, speaks at a news conference with US Secretary of State Antony Blinken, right, and EU Trade Commissioner Valdis Dombrovskis, left, during the US-EU Trade and Technology Council meeting in College Park, Maryland, on Dec. 5. *Photographer: Ting Shen/Bloomberg*


By [Ewa Krukowska](#), [Jennifer A Dlouhy](#) and [Laura Millan Lombrana](#)  
December 20, 2022 at 11:00 AM GMT

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## France Demands Tougher EU Response to US Climate Law

- Le Maire says Inflation Reduction Act endangers EU industry
- No option excluded in EU response to US, Le Maire says



*Bruno Le Maire* *Photographer: Valeria Mongelli/Bloomberg*

By [Alan Katz](#) and [William Horobin](#)  
November 7, 2022 at 6:46 AM GMT Updated on November 7, 2022 at 8:45 AM GMT

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## China Mulls Protecting Solar Tech Dominance With Export Ban

- Export ban considered for technology used to make solar wafers
- China accounts for 97% of global output for the wafers

By [Dan Murtaugh](#)  
January 26, 2023 at 7:57 PM GMT

Source: Bloomberg LP

Scaling up clean power deployment

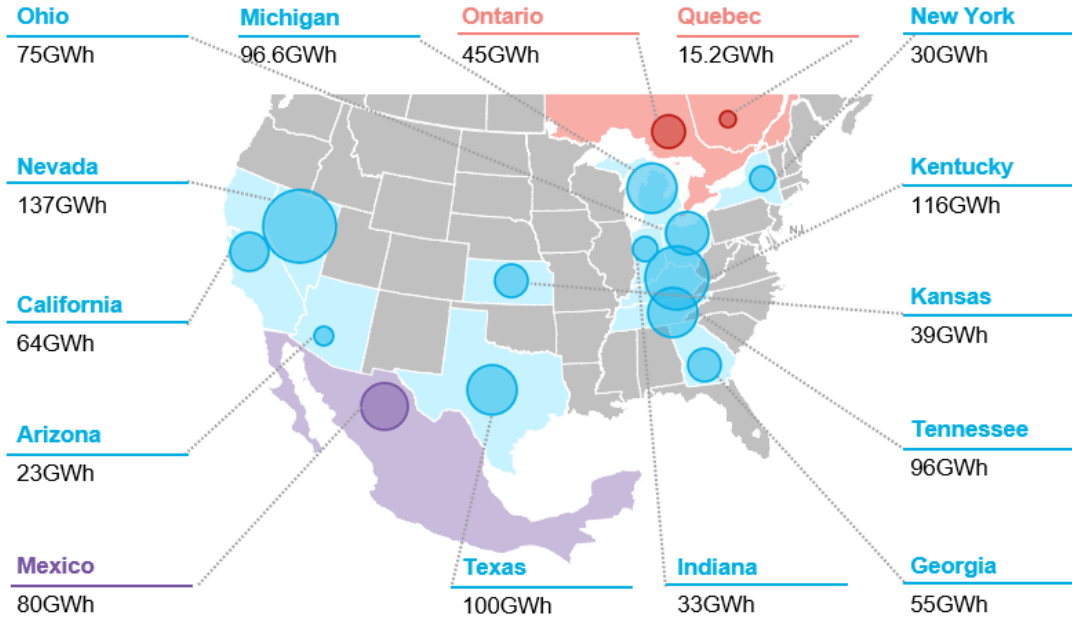
# US passes landmark climate legislation



Source: Bloomberg LP

# Battery manufacturing capacity are on the rise

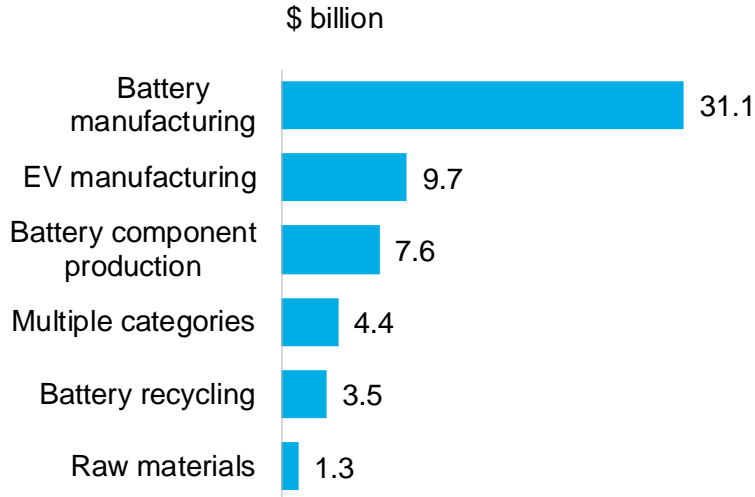
## Battery manufacturing projects announced since IRA passage



Source: BloombergNEF. Note: Dates for fully commissioned plants correspond to the data when the last phase was commissioned. Bubble size corresponds total capacity commissioned, under construction and announced.

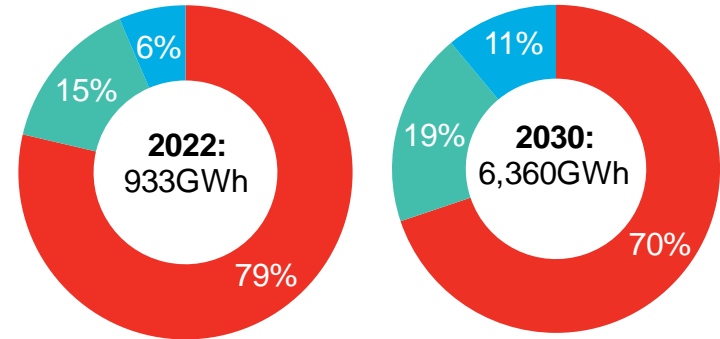
# Battery investments and manufacturing capacity are on the rise

## North America EV and battery investments planned post-IRA



Source: BloombergNEF, company press releases. Note: Includes investments in the North America region through April 3, 2023. 'Multiple categories' investments do not disclose how much is dedicated to each category.

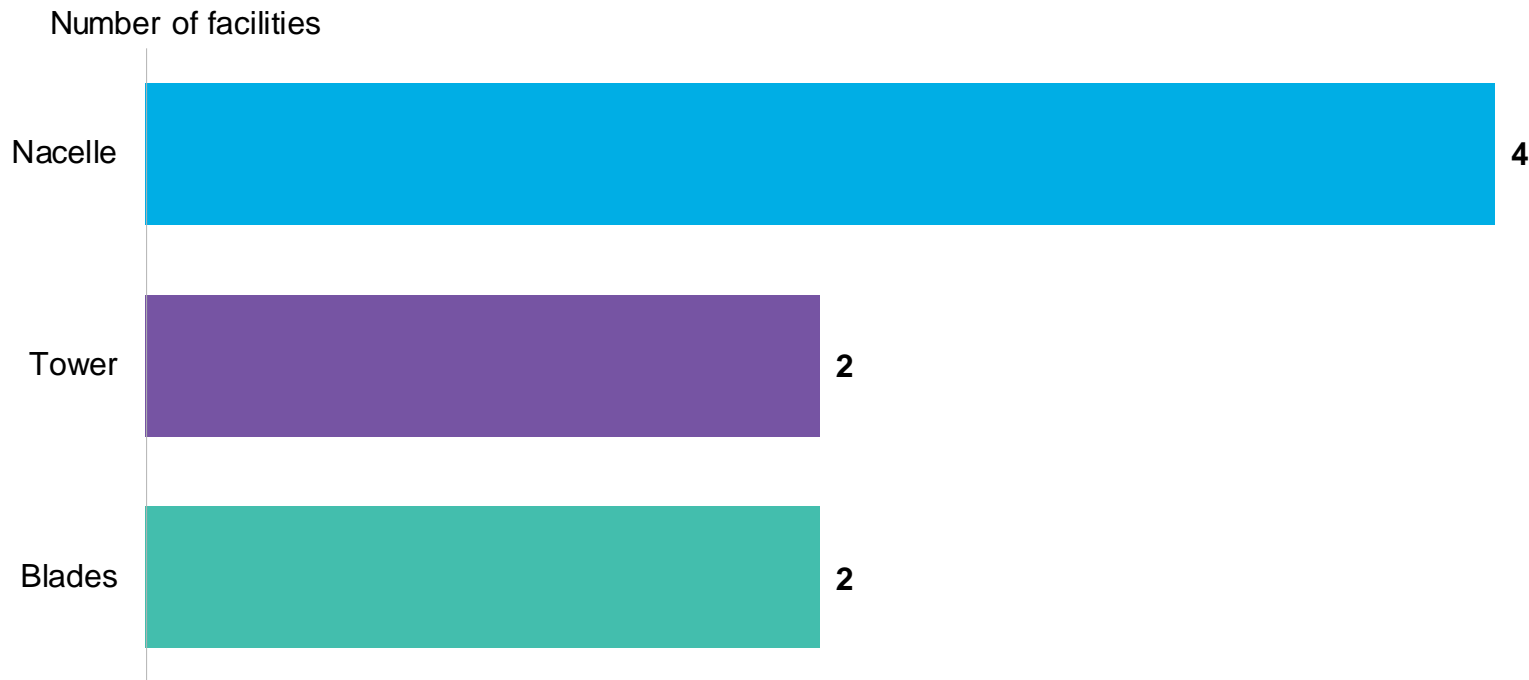
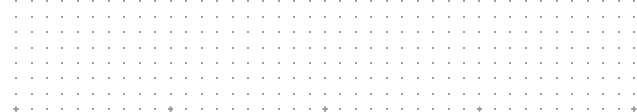
## Global Li-ion cell manufacturing capacity



■ APAC ■ EMEA ■ AMER

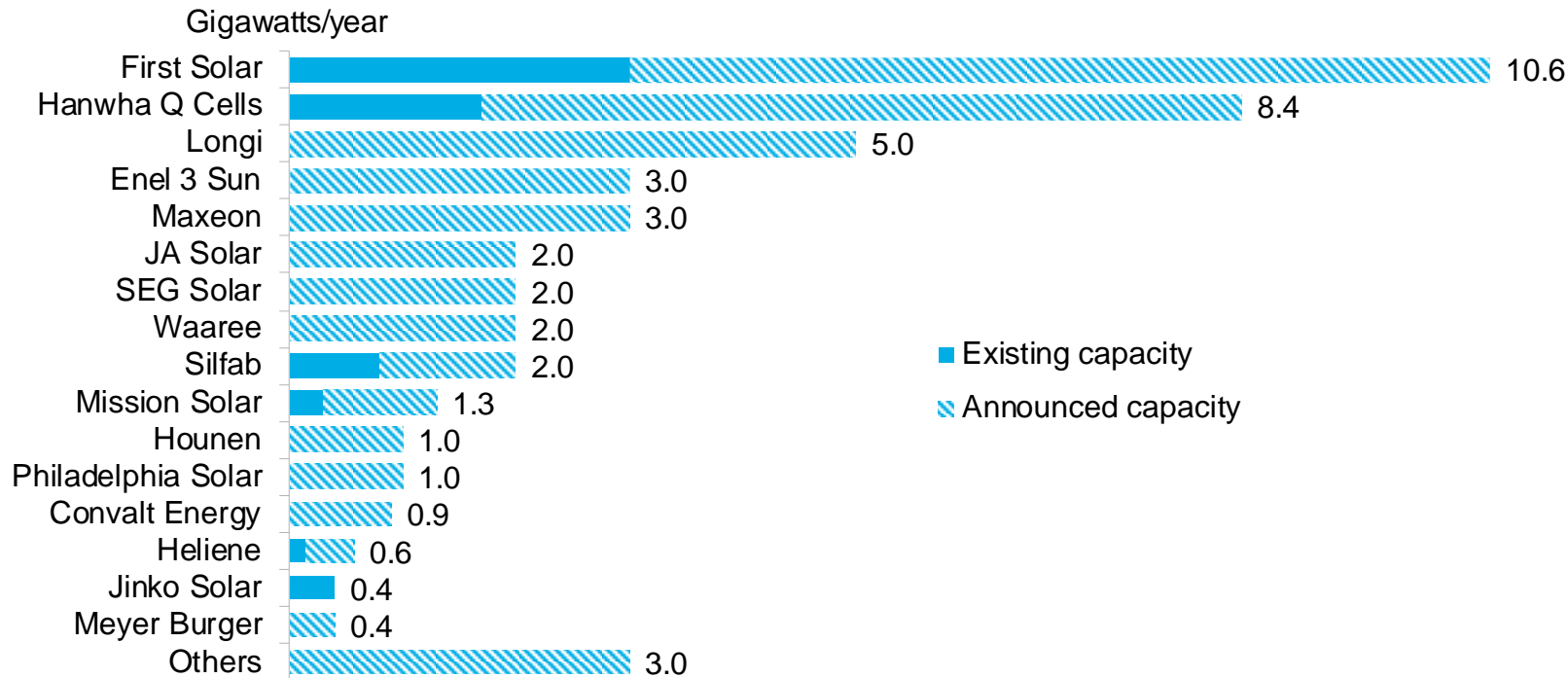
Source: BloombergNEF

# IRA has also driven wind plants to expand and reopen



Source: American Clean Power Association, BloombergNEF. Note: Only includes onshore wind facilities. Nacelle includes assembly and component manufacturing.

# IRA has inspired a huge influx of solar module factory announcements

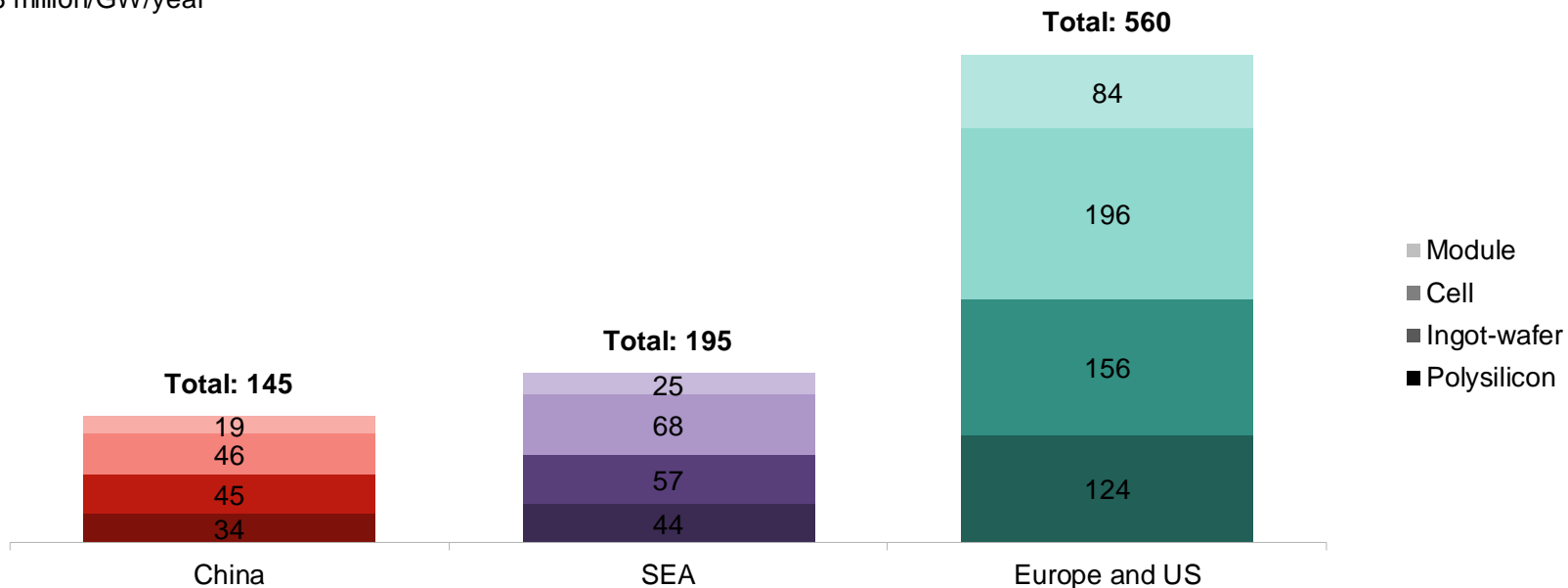


Source: BloombergNEF

# Shifting to local manufacturing often comes at added cost

## Estimated per unit capex for solar factories, by geography

\$ million/GW/year



Source: BloombergNEF, company filings, interviews



Scaling up clean power deployment

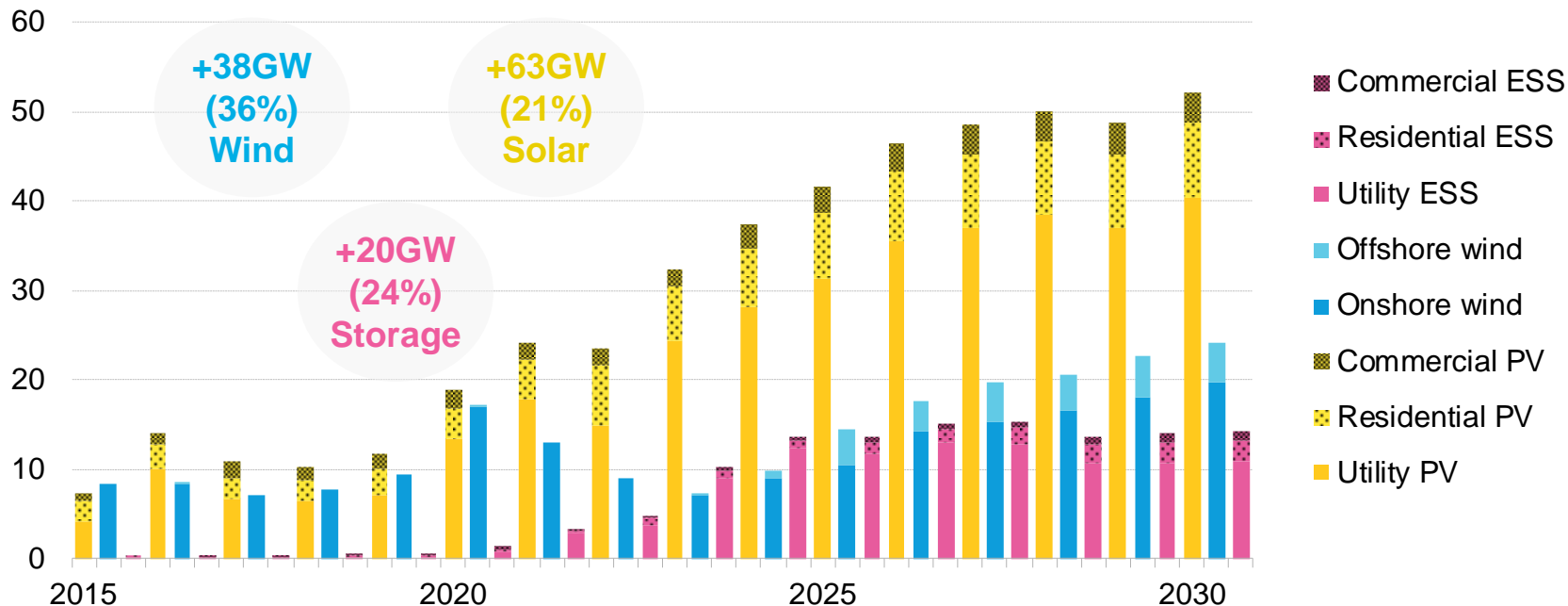
**There are many positive signs that  
clean power will overcome these  
challenges**



Source: Bloomberg LP

# IRA drove an increase of over 100GW in our clean energy forecast to 2030

Gigawatts

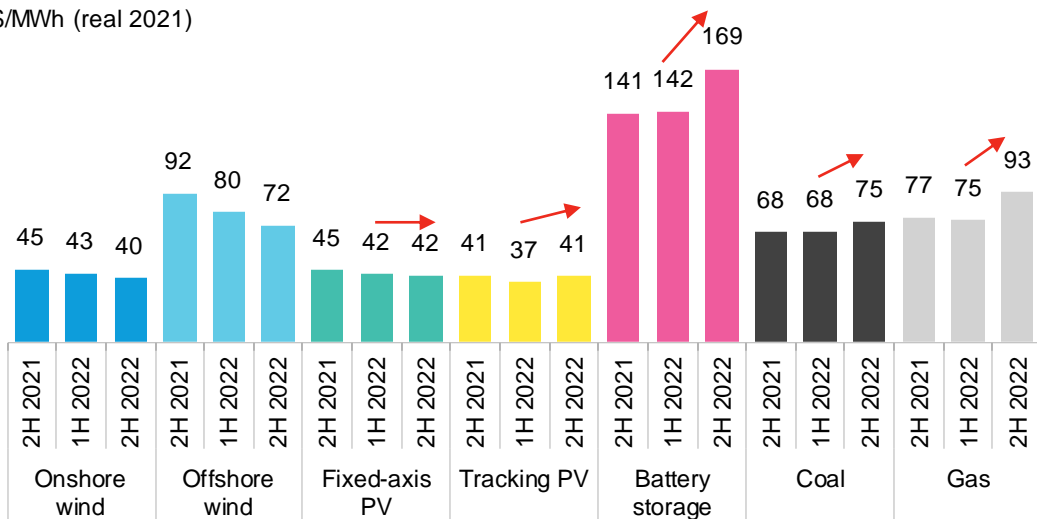


Source: BloombergNEF. Note: ESS = energy storage system.

# LCOEs are rising for the first time in history, driven by supply chains, inflation and pricier debt

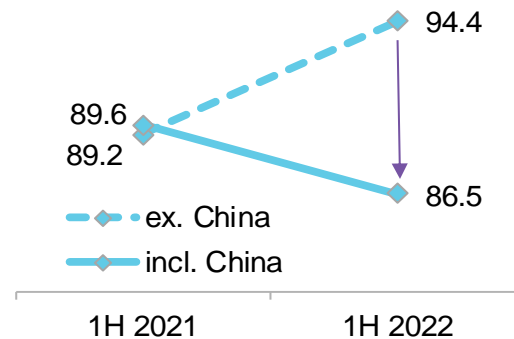
## Change in global LCOEs, 2H 2021 through 1H 2022

\$/MWh (real 2021)



## Impact of China on offshore wind LCOE benchmark

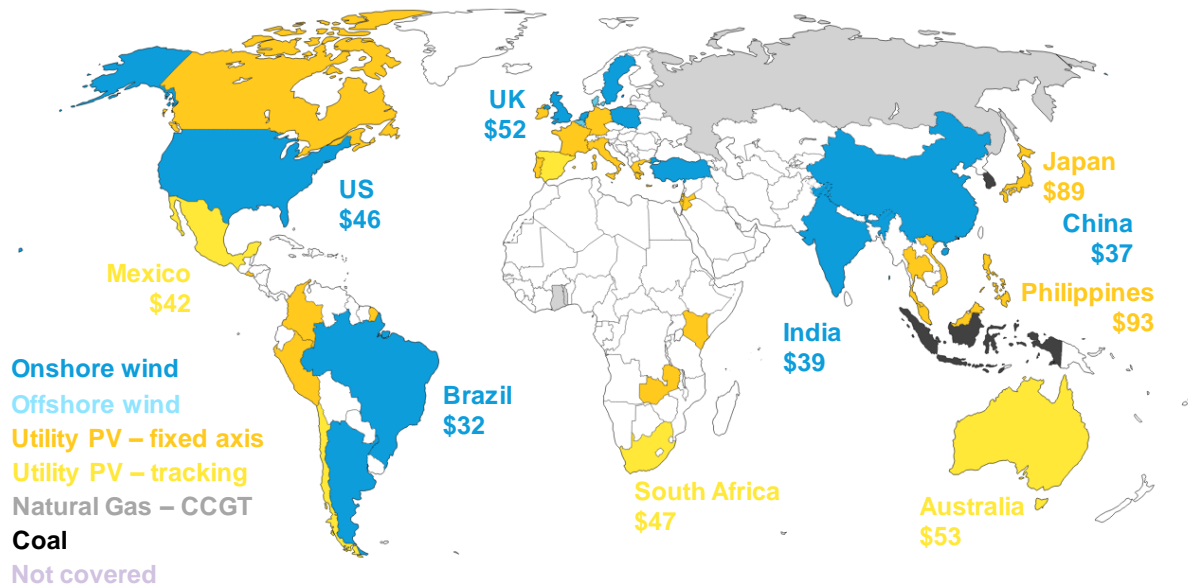
\$/MWh (nominal)



Source: BloombergNEF. Note: The global benchmarks are country-weighted levelized cost of electricity (LCOE) averages using the latest annual capacity additions. Offshore wind includes offshore transmission costs. LCOEs do not include subsidies or tax credits.

# Solar or onshore wind is the cheapest source of electricity in countries representing 96% of global electricity generation

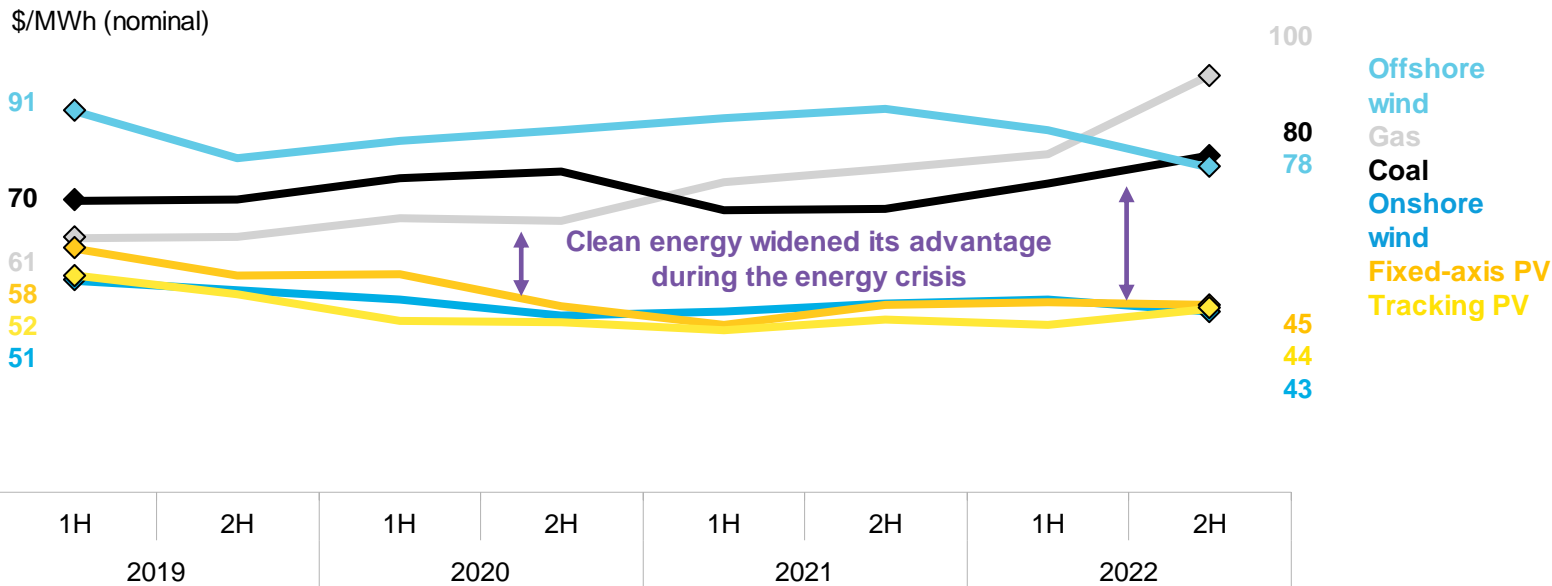
Cheapest source of bulk generation, 2H 2022



Source: BloombergNEF.

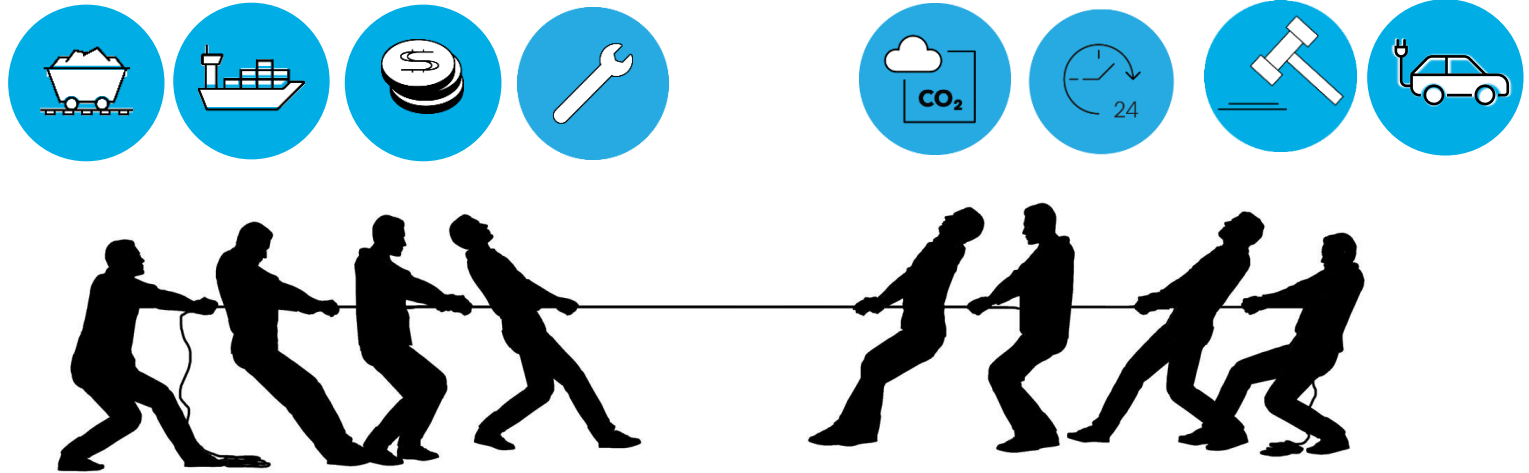
# Clean energy still has the enduring advantage

## Global levelized cost of electricity benchmarks



Source: BloombergNEF

# Buffeted by competing forces, where does the momentum lie?



Source: Clipart-Library

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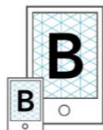
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