Global Trends in Green Energy

IEA-GOT CP Energy Transition Summit
Stavanger, 28 October 2021

Michael Liebreich

Founder and CEO

Liebreich Associates

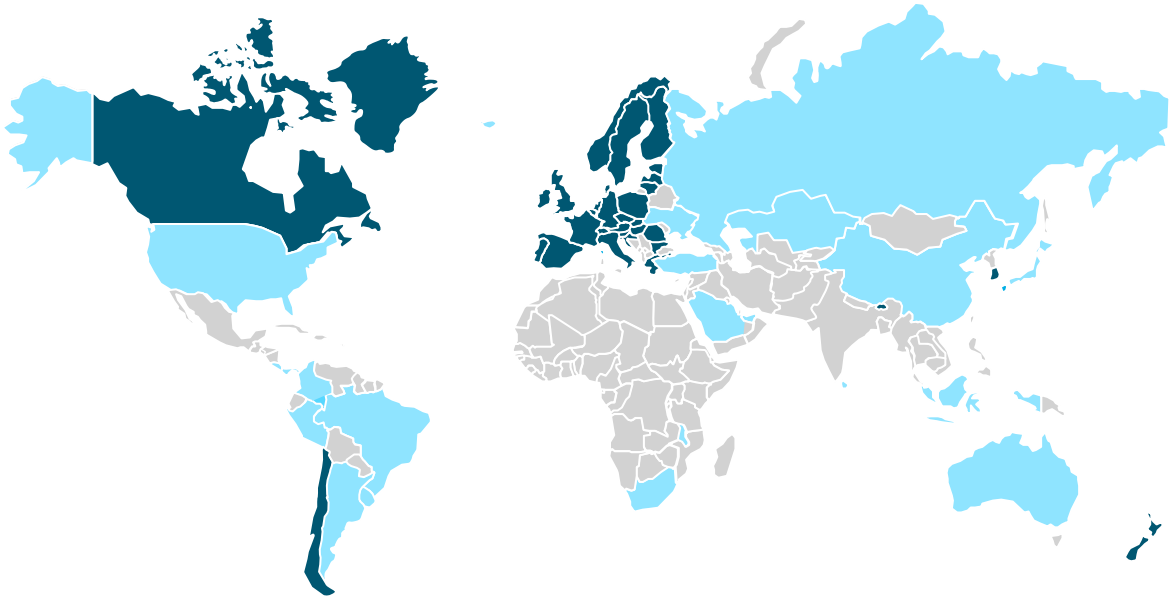
Background

Liebreich Associates

Source: COP26

COP26 – net zero pledges to date

Liebreich Associates



Announced/likely net zero target

Domestic legislation in place or in parliament

	2050	2060
Global economy	64%	84%
Global population	22%	47%
Global emissions	36%	71%

Note: as at October 2021, GDP in real USD, not PPP adjusted

Sources: Liebreich Associates, European Commission, UN, IMF, Climate Home

Australia 2015

Liebreich Associates

“This is coal - don't be afraid, don't be scared!”

Scott Morrison, Prime Minister of Australia
February 2017

Image: Bloomberg

Australia 2021

Liebreich Associates

> We will set a target to achieve net zero by 2050, and have a clear plan for achieving it.

Scott Morrison, Prime Minister of Australia
October 2021

Image: Bloomberg

Fridays For Future

Liebreich Associates

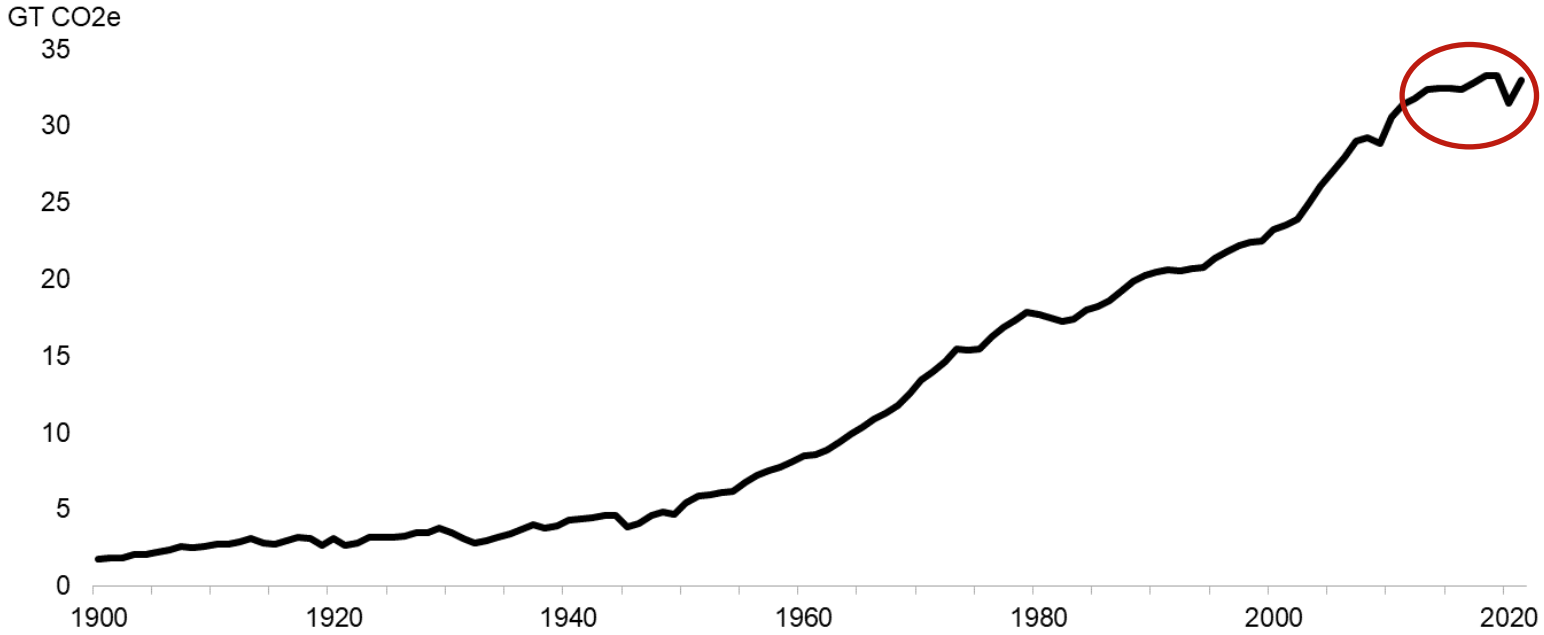
> Basically, nothing is being done to halt this crisis despite all the beautiful words and promises from our elected officials.

Greta Thunberg
Founder, School Strike for Climate

Image: AFP

Global CO2 emissions from fuel combustion

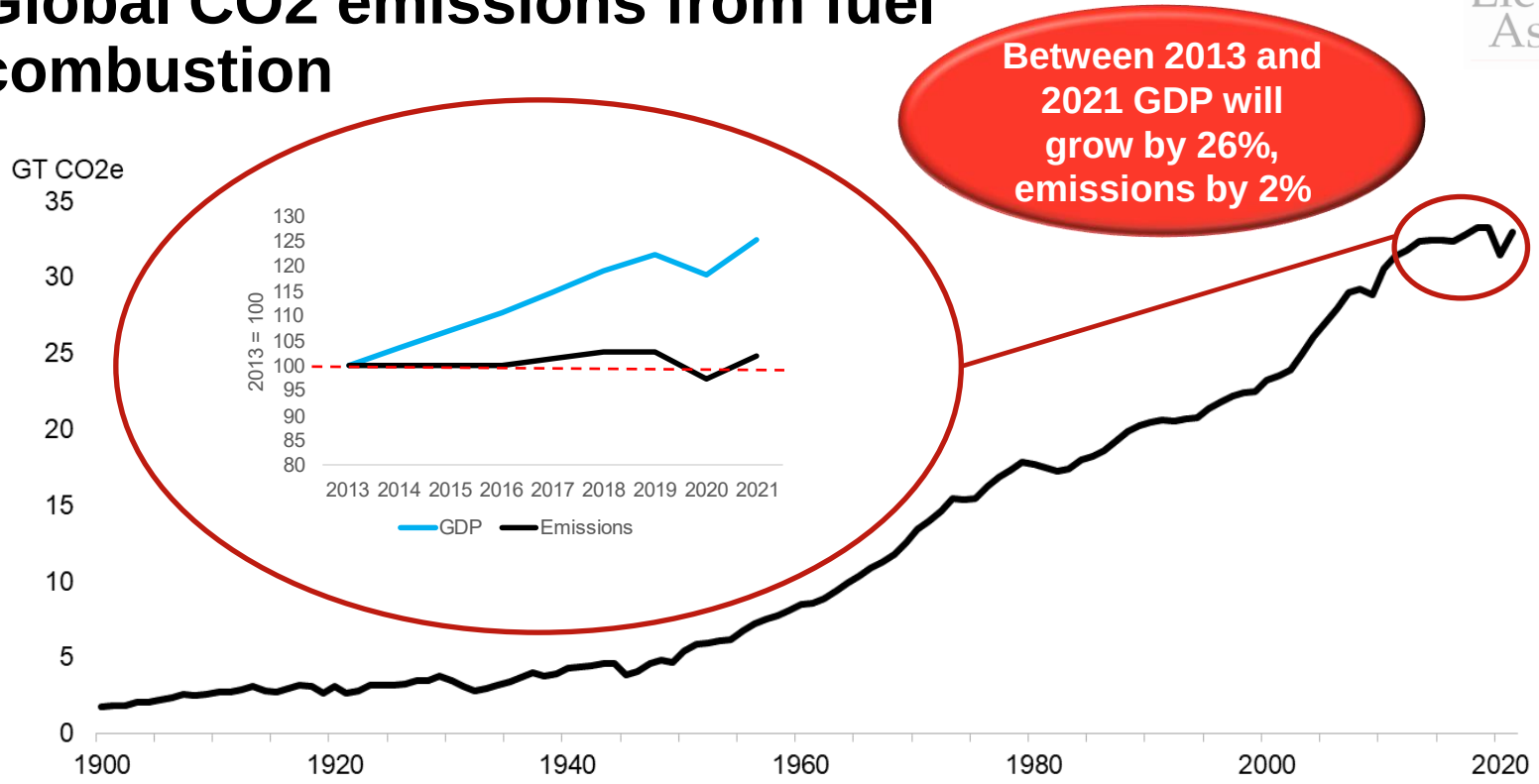
Liebreich Associates



Source: Liebreich Associates, IEA, IMF

Global CO2 emissions from fuel combustion

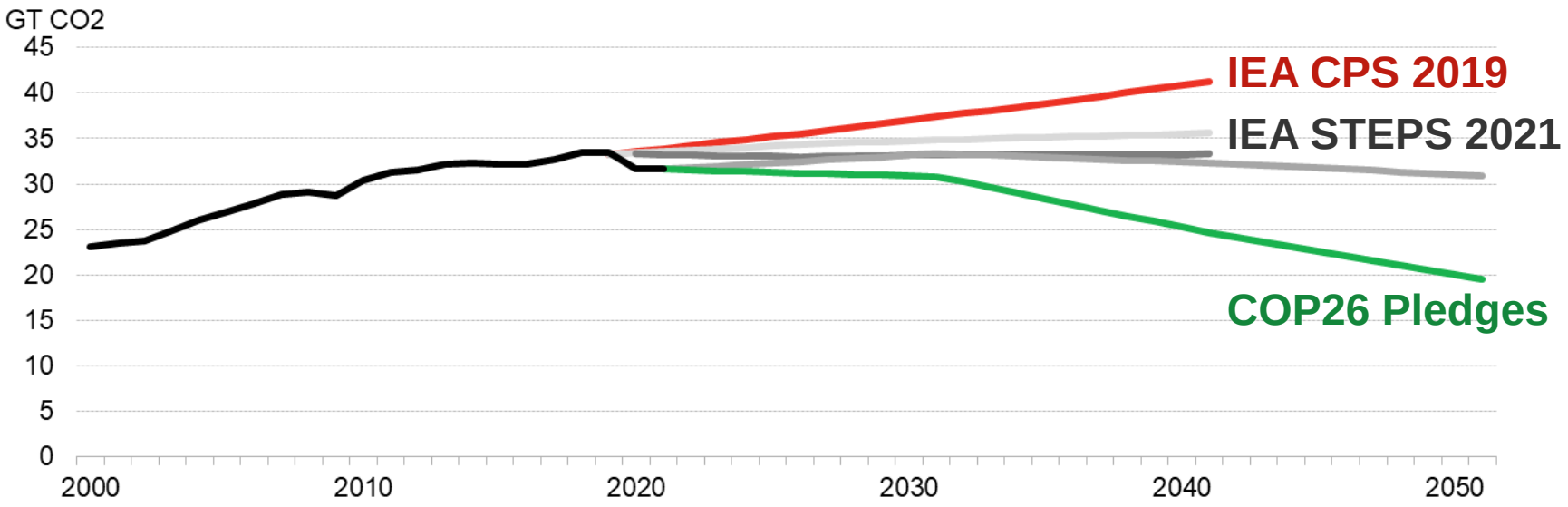
Liebreich Associates



Source: Liebreich Associates, IEA, IMF

IEA WEO 2021: fossil fuel CO2 emissions

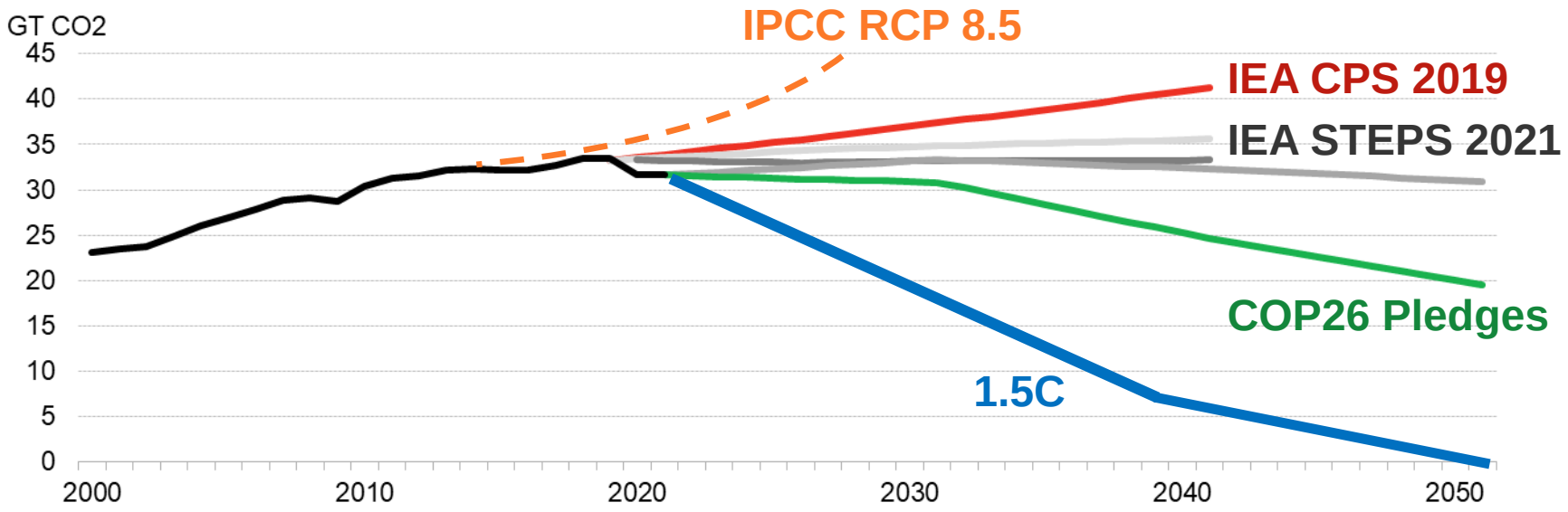
Liebreich Associates



Source: IEA; Breakthrough Institute; Zeke Hausfather; Liebreich Associates

IEA WEO 2021: fossil fuel CO2 emissions

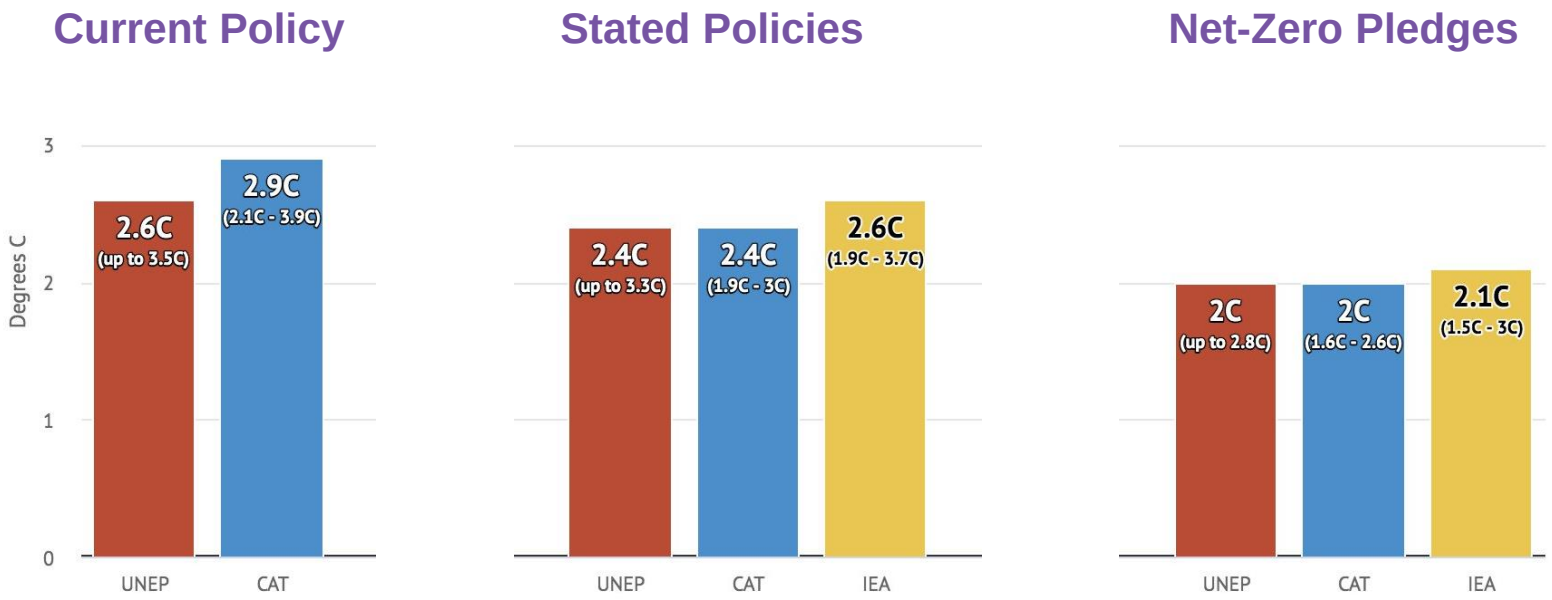
Liebreich Associates



Source: IEA; Breakthrough Institute; Zeke Hausfather; Liebreich Associates

2100 warming over pre-industrial age

Liebreich Associates



Source: UNEP; IEA; Climate Action Tracker; CarbonBrief; Liebreich Associates

Energy

Liebreich Associates

Source: NASA

Unsubsidised clean energy world records 2015

Liebreich Associates

Solar PV

Country: UAE
Bidder: AQWA
Signed: January 2015
Construction: 2017

US$ 5.8 c/kWh

Onshore wind

Country: South Australia
Bidder: Neoen
Signed: 2014
Construction: 2016

US$ 6.0 c/kWh

Offshore wind

Country: Horns Rev, Denmark
Bidder: Vattenfall
Signed: Feb 2015
Construction: 2017

US$ 12.1 c/kWh

Note: images are illustrative only

Source: Various manufacturers and project developers

Unsubsidised clean energy world records 2021

Liebreich Associates

Solar PV

Country: Saudi Arabia
Bidder: ACWA Power
Signed: April 2021
Construction: 2021-2022

US$ 1.04 c/kWh

Onshore wind

Country: Mexico
Bidder: Neoen
Signed: Nov 2017
Construction: 2019

US$ 1.77 c/kWh

Offshore wind

Country: Germany
Bidder: Dong/ENBW
Signed: 2016
Construction: 2024

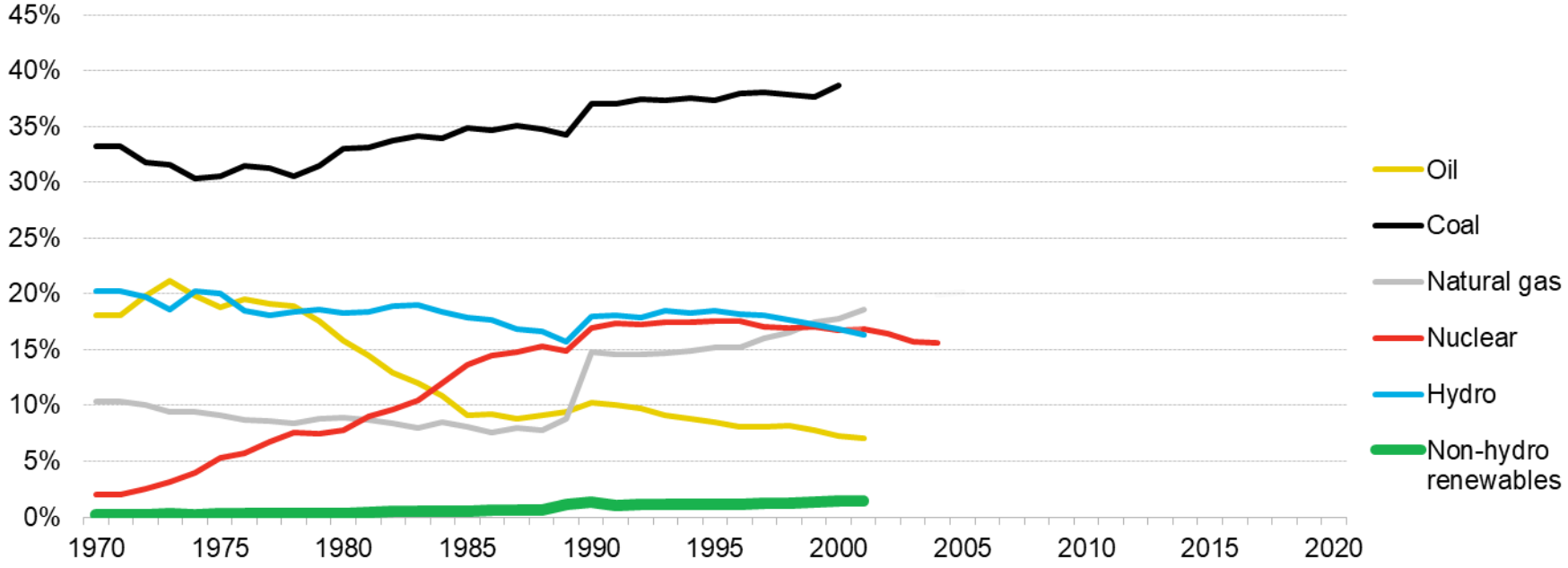
US$ 4.9 c/kWh

Note: images are illustrative only

Source: Various manufacturers and project developers

Global share of power generation by source 1971 - 2020

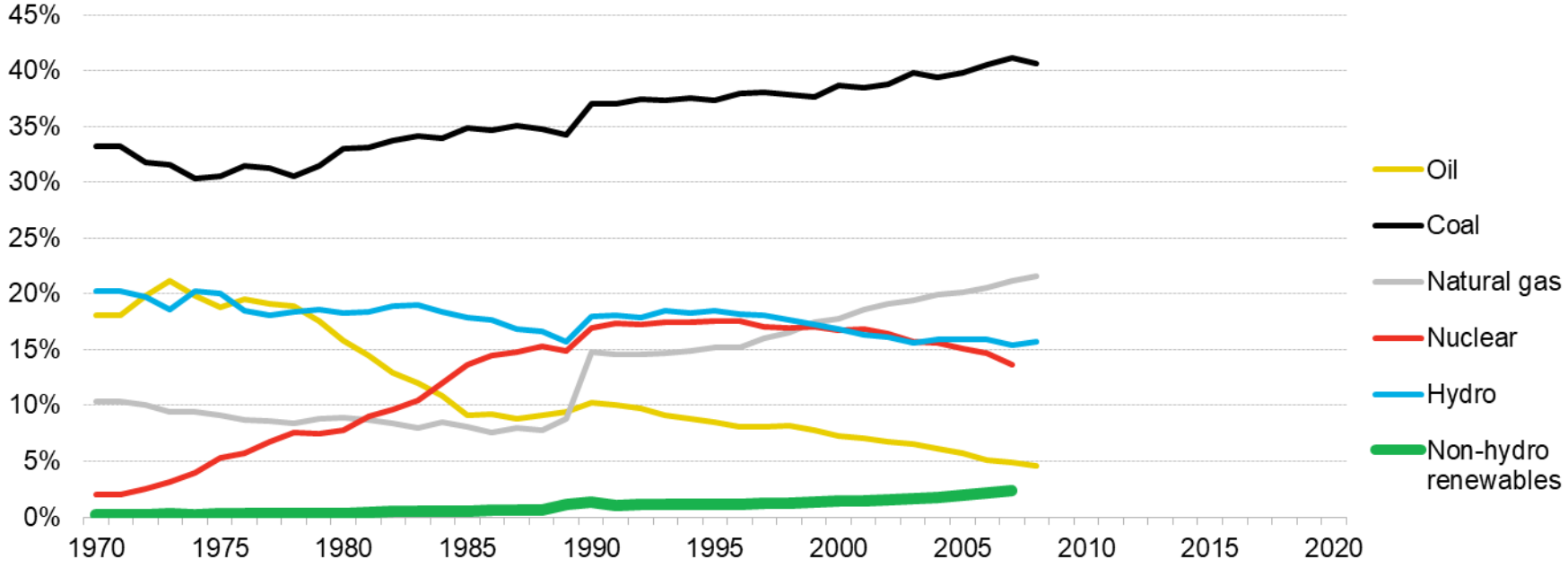
Liebreich Associates



Source: Liebreich Associates, IEA, BP, World Bank

Global share of power generation by source 1971 - 2020

Liebreich Associates



Source: Liebreich Associates, IEA, BP, World Bank

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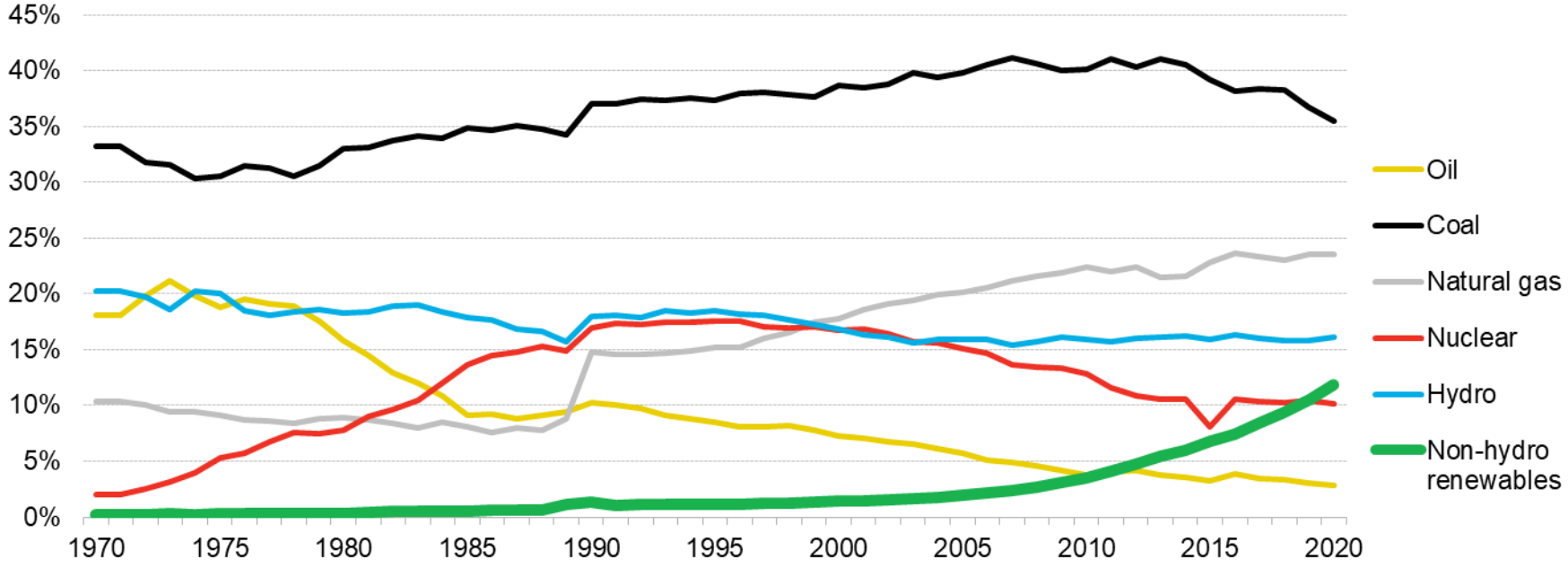
Liebreich Associates

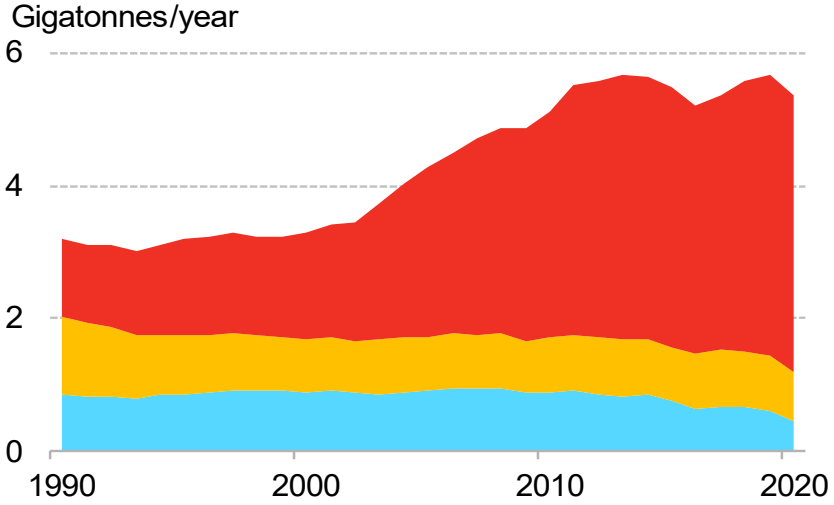


Source: Liebreich Associates, IEA, BP, World Bank

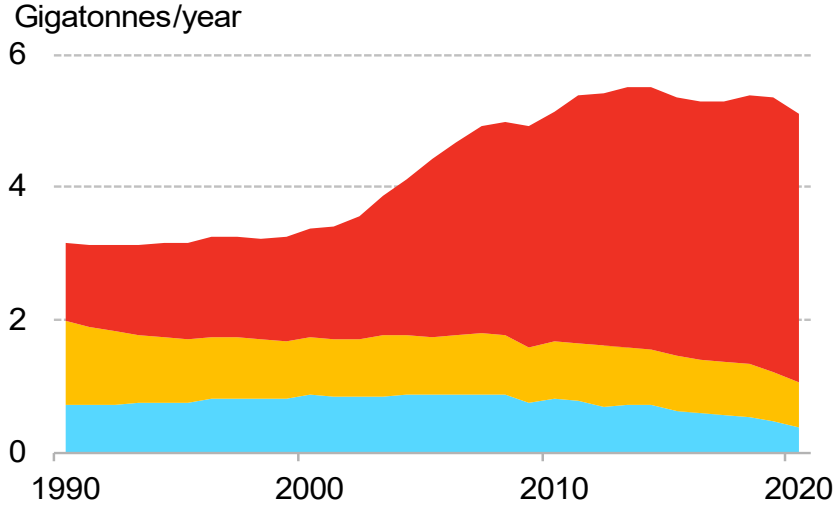
Global thermal coal production and consumption by region, 1990 – 2020

Liebreich Associates

Coal production



Coal consumption



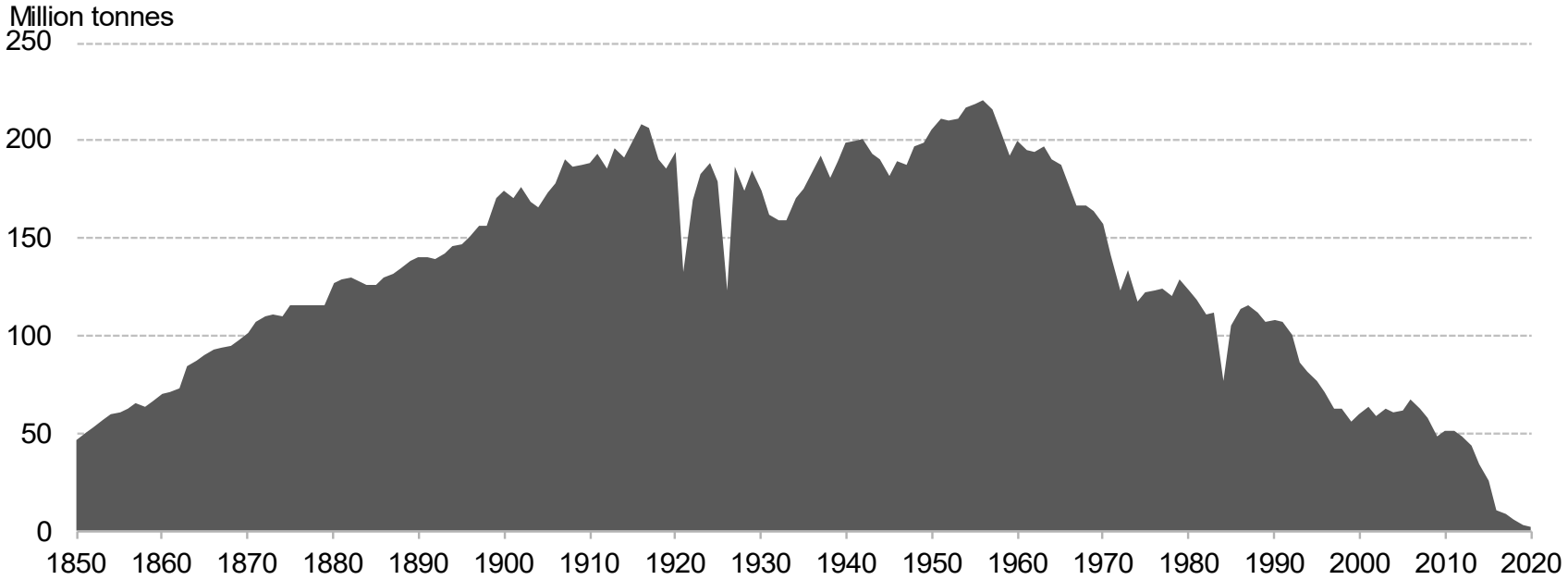
AMER EMEA APAC

Note: Adjusted to standard coal equivalent

Source: Liebreich Associates; BP Statistical Review

UK coal consumption 1850 – 2020

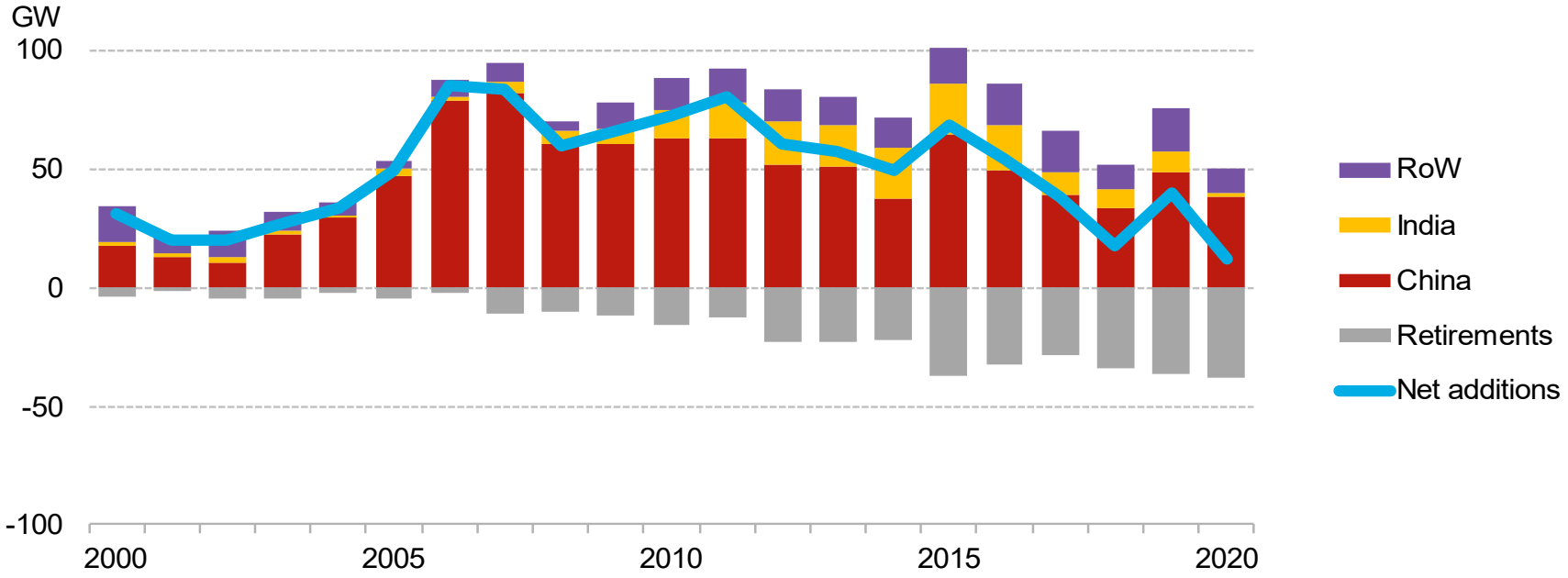
Liebreich Associates



Source: BEIS, Prof. David Rutledge, BNEF NEO 2019; Liebreich Associates

Net new coal generation capacity 2000 – 2020

Liebreich Associates

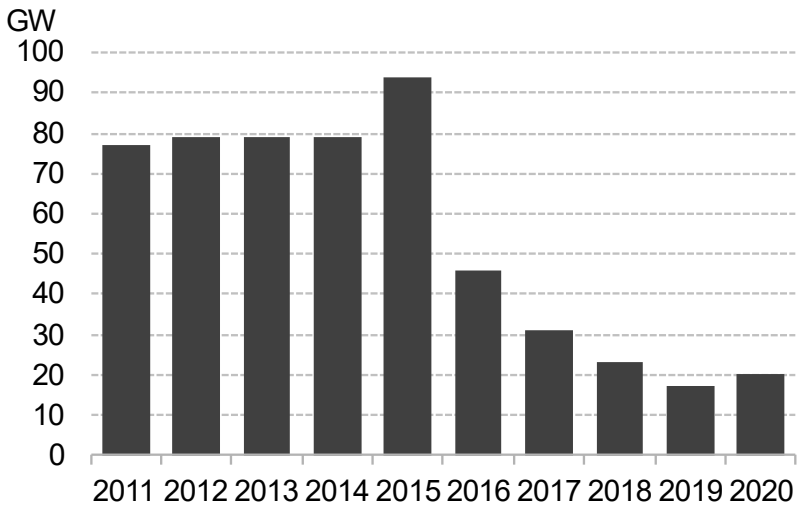


Source: Liebreich Associates; Coalswarm

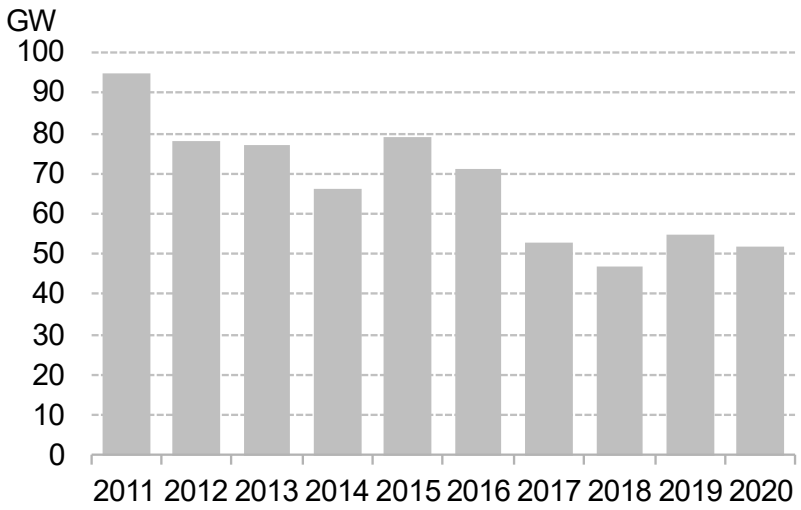
Final investment decisions for coal and gas-fired generation 2011 – 2020

Liebreich Associates

Coal



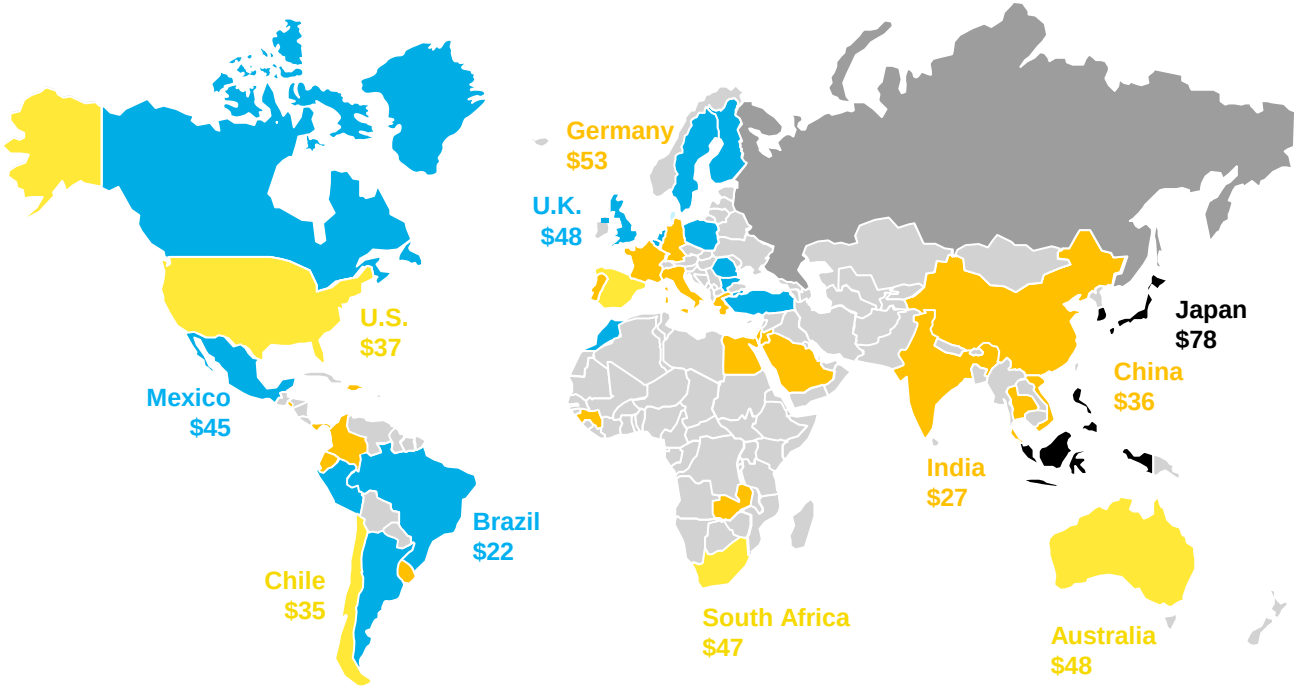
Gas



Source: IEA

Cheapest source of new generation, 1H 2021

Liebreich Associates



Legend

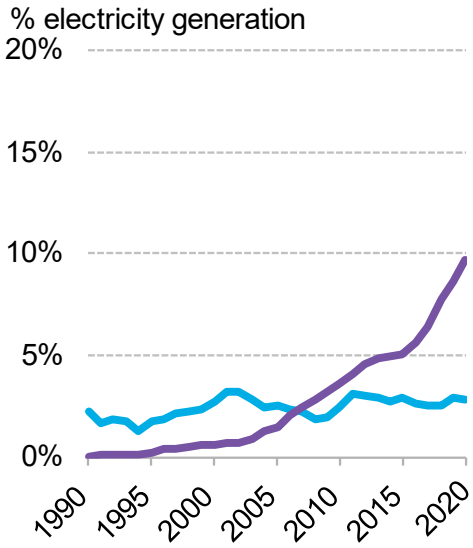
- Onshore wind
- Offshore wind
- Utility PV – fixed axis
- Utility PV – tracking
- Natural Gas – CCGT
- Coal
- Not covered

Source: BloombergNEF, Liebreich Associates

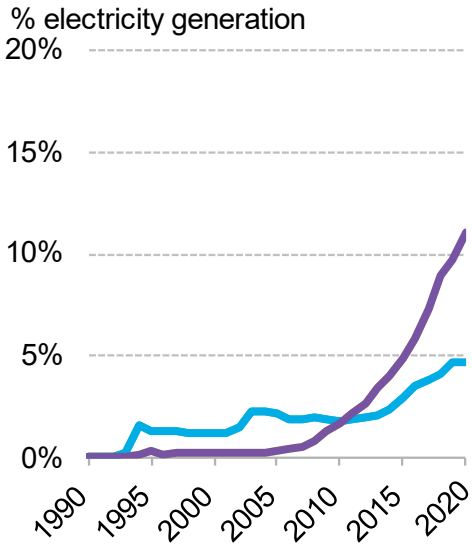
Nuclear vs. non-hydro renewable generation in selected countries 1990 – 2020

Liebreich Associates

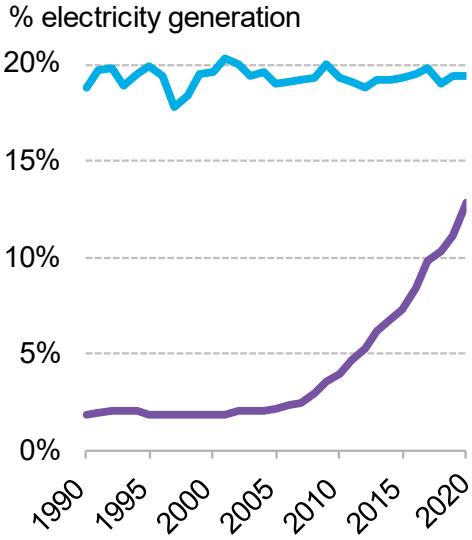
India



China



U.S.



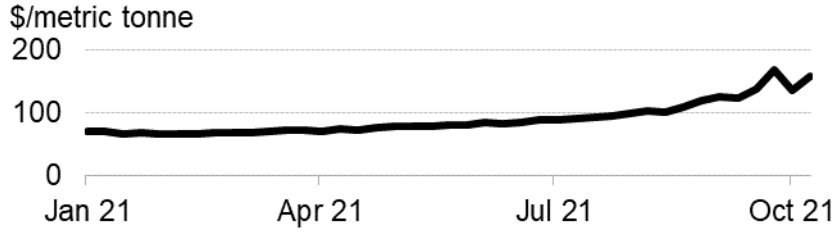
Nuclear Non-hydro renewables

Source: BP; Liebreich Associates

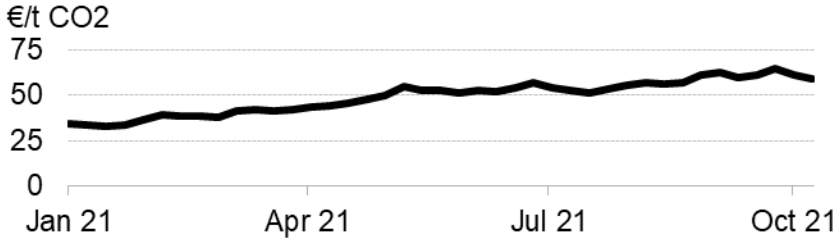
Current price spike

Liebreich Associates

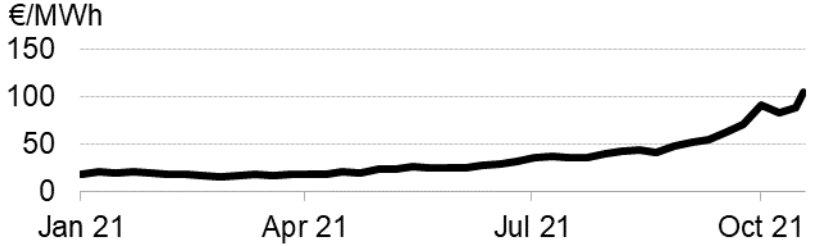
Coal



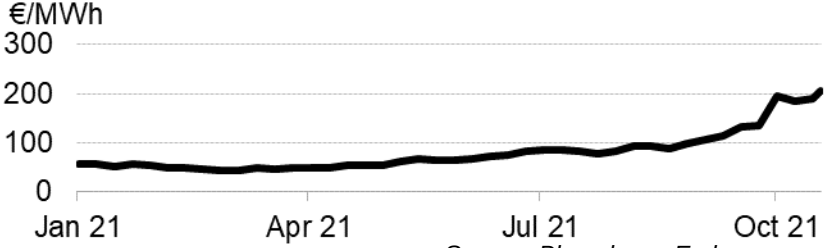
Carbon (EU-ETS)



Natural Gas



Electricity

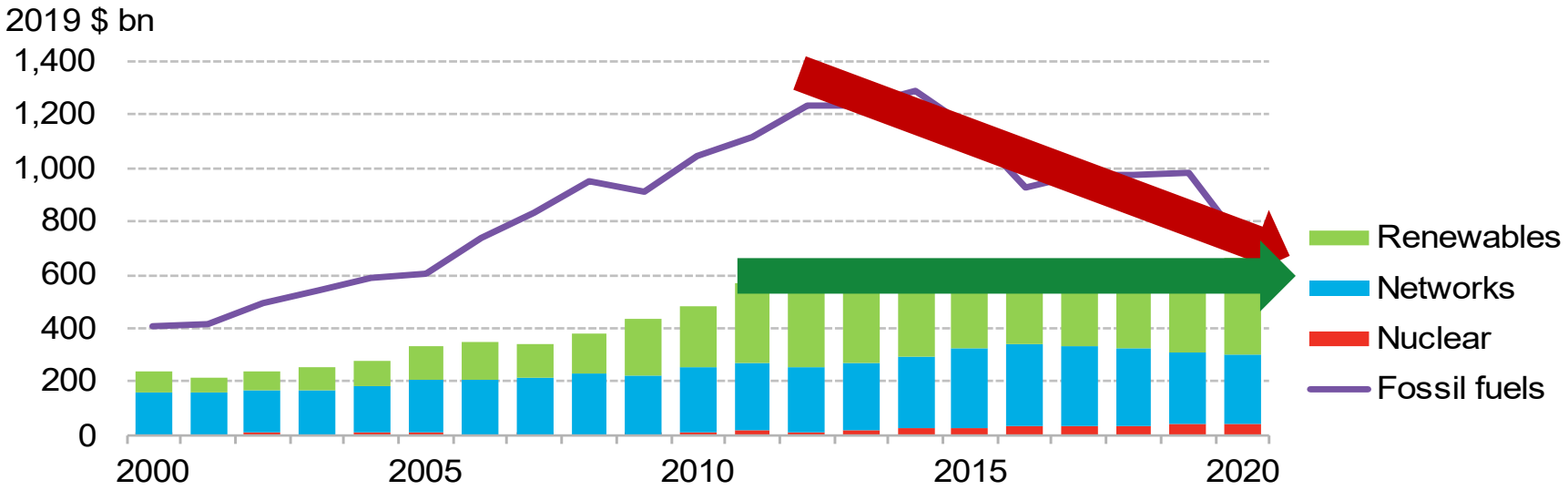


Note: Coal – ARA 1Y Forward, NatGas- TTF 1M Forward, Electricity – DE 1M Baseload Forward

Source: Bloomberg, Ember

Global energy investment by sector 2000-2020

Liebreich Associates



Source: IEA, Liebreich Associates

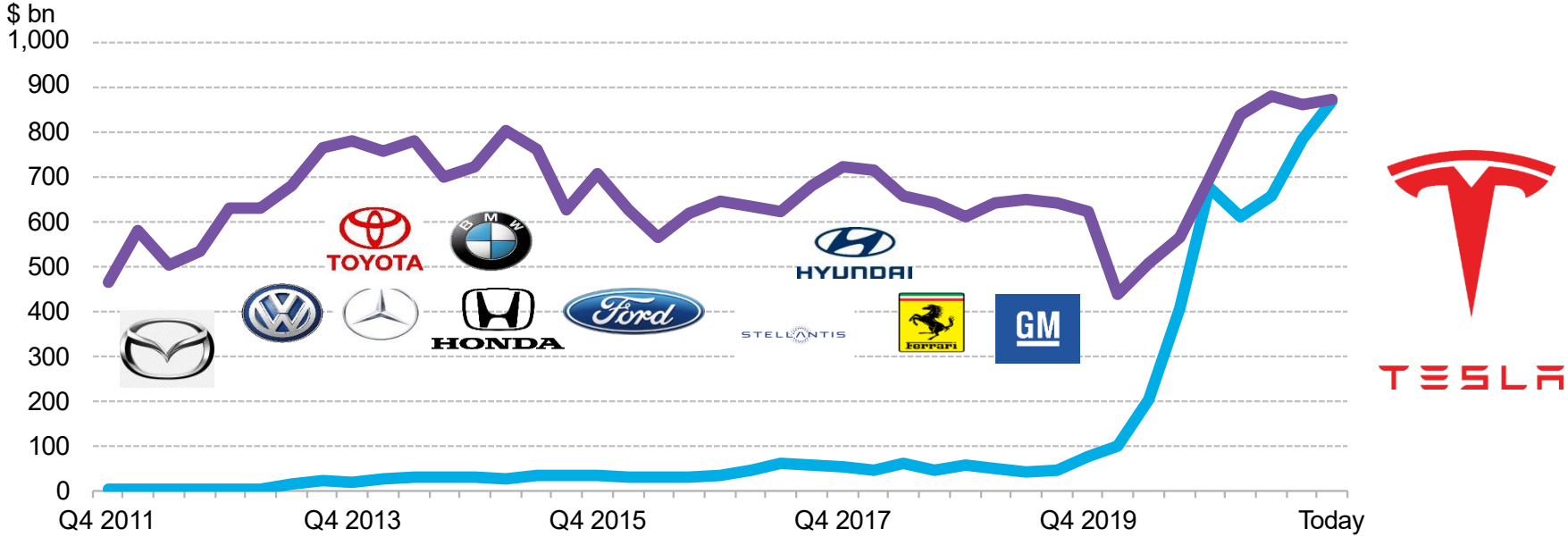
Transport

Liebreich Associates

Source: NASA

Automotive market capitalisations October 2021

Liebreich Associates



Source: Bloomberg, Ycharts, Liebreich Associates

Daimler Benz Ceases Internal Combustion Engine development to focus on BEVs

Liebreich Associates

1885

2020

Images: Daimler Benz

Electric and ICE fleets in comparison

Liebreich Associates

Electric vehicles fleet worldwide

Q4 2021
14 million

Cars and light truck fleet worldwide

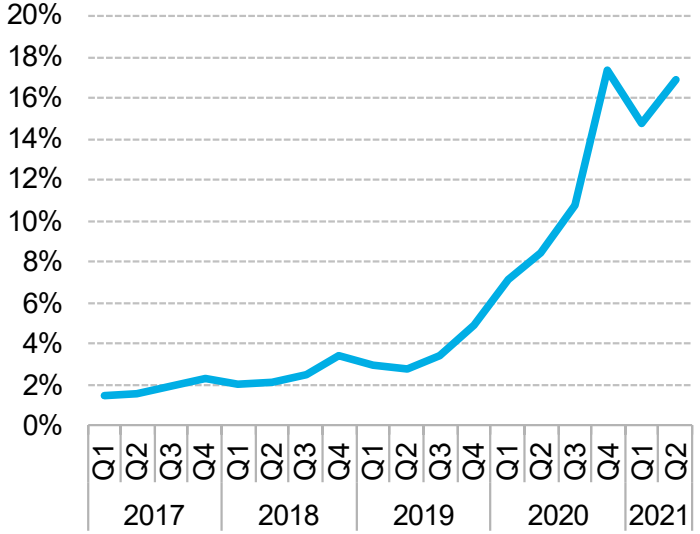
2021
1.4 billion

Source: Liebreich Associates, International Organization of Motor Vehicle Manufacturers

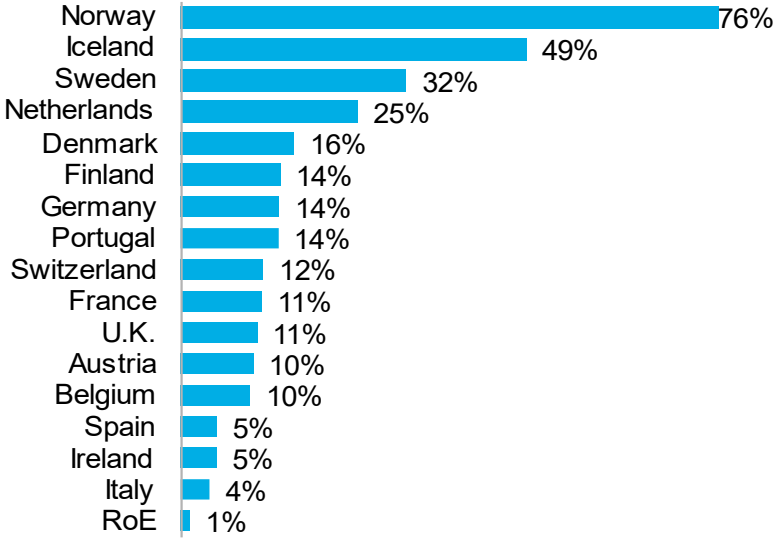
EV sales in Europe

Liebreich Associates

Europe EV share of passenger vehicle sales



EVs share of passenger vehicle sales 2020

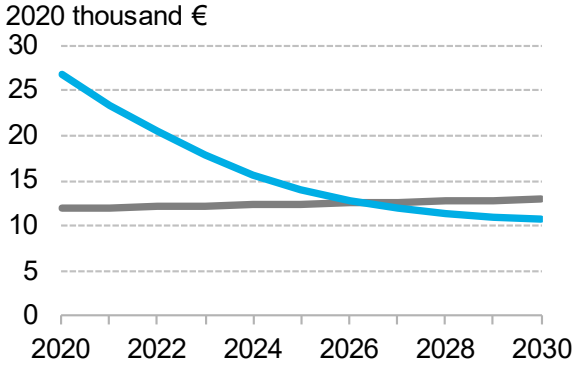


Source: BloombergNEF EVO2021

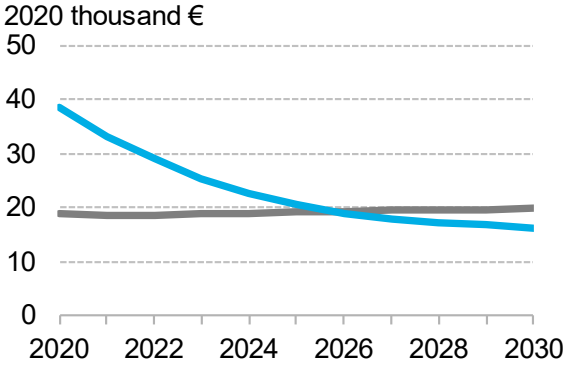
ICE EV sticker price parity in Europe

Liebreich Associates

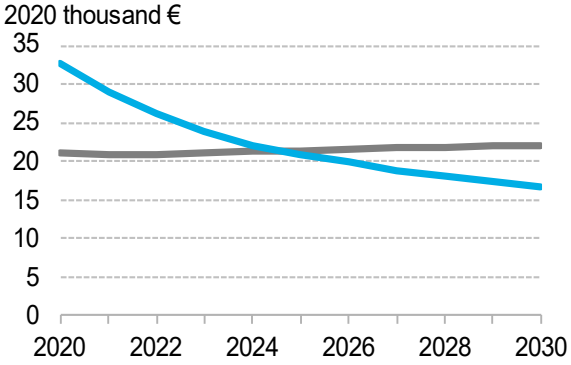
Segment B



Segment C



Light vans



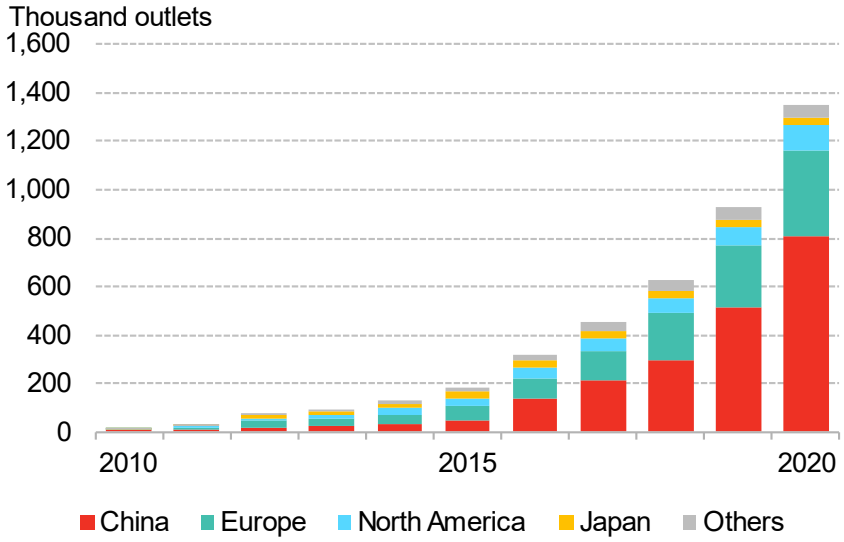
ICE BEV

Source: BloombergNEF, Images:SubPNG, Tesla, Peugeot

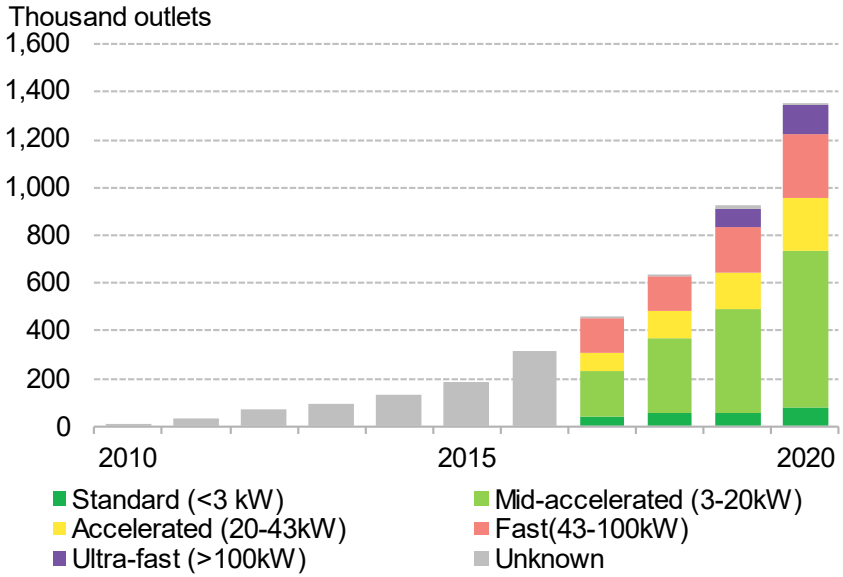
Global public charging infrastructure

Liebreich Associates

By region



By charging speed



Source: BloombergNEF

Not just cars going electric – buses

Liebreich Associates

Images: Thomas Jouley; BYD; Proterra

Not just cars going electric – 2 & 3 wheelers

Liebreich Associates

Images: Toyota; Omastar ; Kalkhoff; Jetson; Harley Davidson; Jump

Not just cars going electric – commercial vehicles

Liebreich Associates

Images: Tesla; Starship Technologies; Ehang; Zunum; Daimler; Dpost; UPS/Arrival

Not just cars going electric

Liebreich Associates

Image: Caterpillar; Toyota; Pon Equipment; Fendt

Not just cars going electric – ships

Liebreich Associates

Images: Alf Kare Aesobo; Kongsberg; Enercon, ABB; cision.com

Not just cars going electric

Liebreich Associates

Images: Volocopter, Lilium, Pipistrel; Airbus; Zunum; NASA

Hydrogen

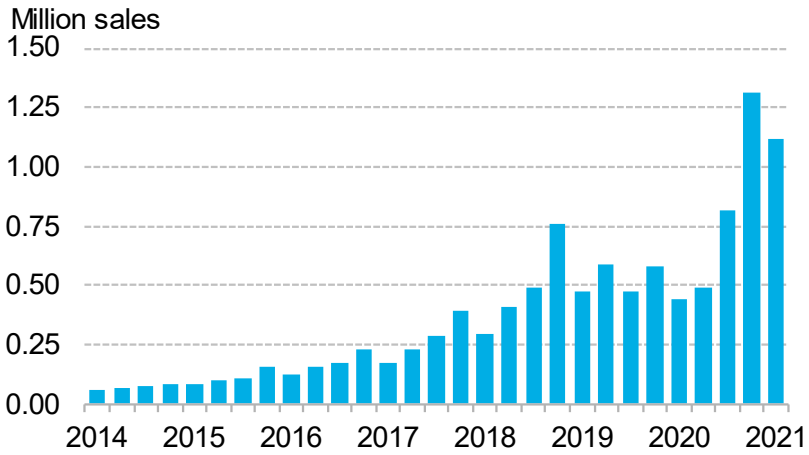
Liebreich Associates

Image: Wikimedia Commons

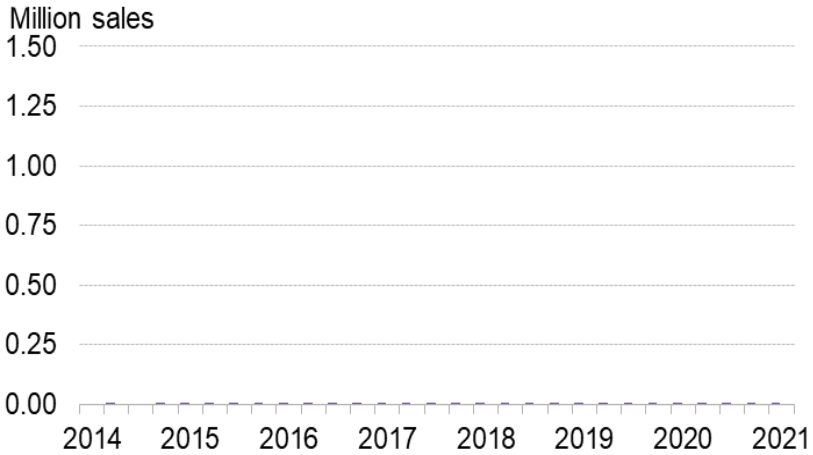
Global BEV vs. FCV sales quarterly

Liebreich Associates

Battery electric vehicles



Fuel cell vehicles

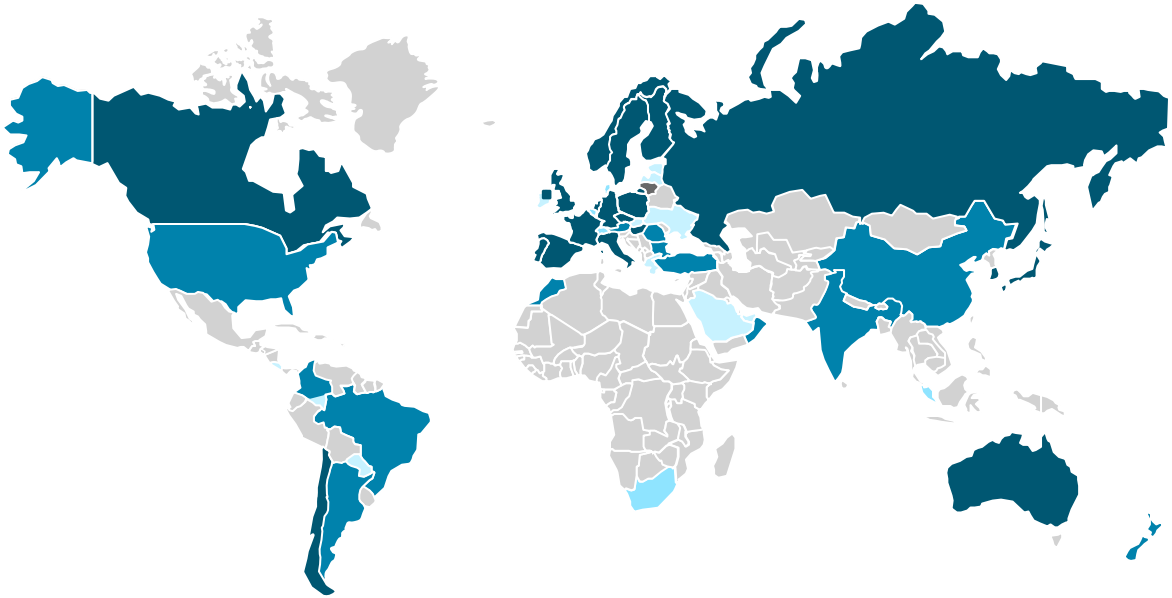


Note: Includes PHEVs

Source: BNEF, Marklines

Hydrogen policy support

Liebreich Associates

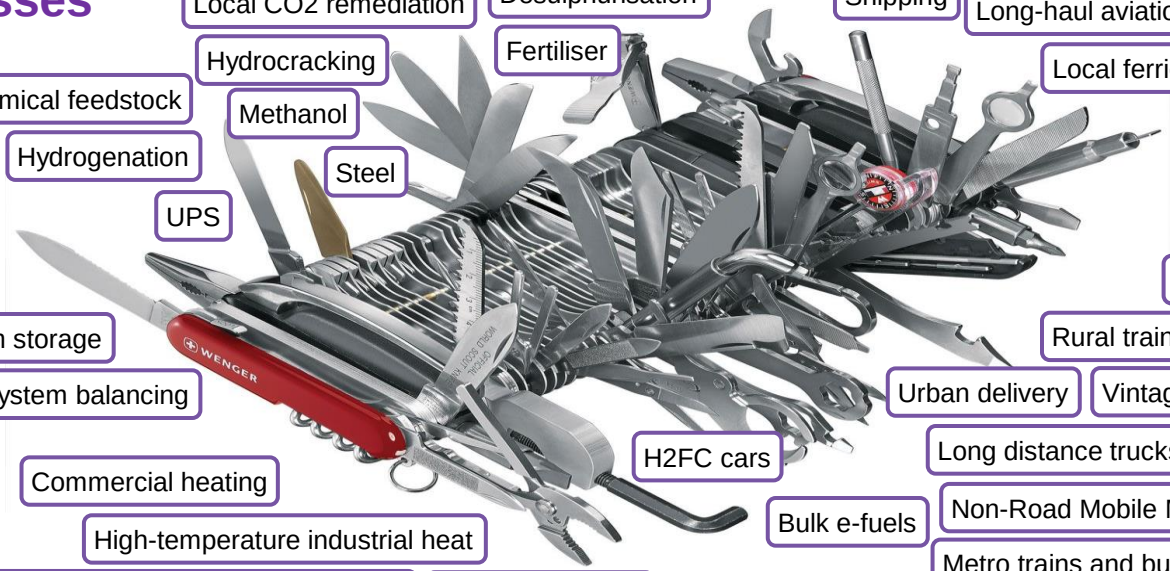


- National hydrogen strategy in place
- National hydrogen strategy in preparation
- Support for pilot and demonstration projects
- Initial policy discussions

Source: BloombergNEF, Joe Goodman for Carbon Brief based on Ludwig-Bölkow-Systemtechik GmbH and World Energy Council's German chapter

Clean Hydrogen Swiss Army Knife

Liebreich Associates



Chemicals & processes

Local CO2 remediation
Desulphurisation
Hydrocracking
Fertiliser
Chemical feedstock
Methanol
Hydrogenation
Steel

Aviation & shipping

Short-haul aviation
Light aviation
Shipping
Long-haul aviation
Local ferries
Coastal and river vessels
Medium-haul aviation

Power system

Clean power imports
UPS
Island grids
Generators
Long-term storage
Power system balancing

Land transport

Regional trucks
2 and 3-wheelers
Rural trains
Remote trains
Urban delivery
Vintage vehicles
Long distance trucks and coaches
Non-Road Mobile Machinery
Metro trains and buses

Heat

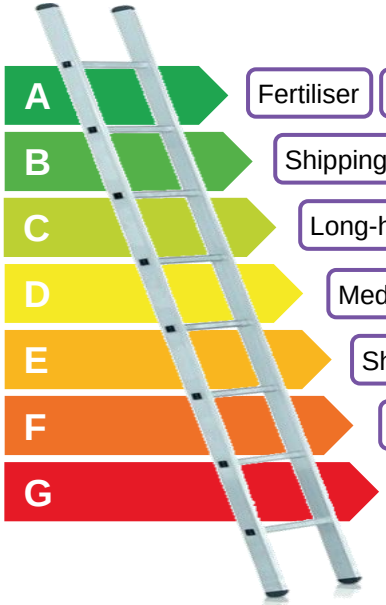
H2FC cars
Bulk e-fuels
Commercial heating
High-temperature industrial heat
Mid/Low-temperature industrial heat
Domestic heating

Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, 2021.Concept credit: Adrian Hiel, Energy Cities. Image: Wenger (concept credit: Paul Martin). CC-BY 3.0

Clean Hydrogen Ladder

Liebreich Associates

Unavoidable



A	Fertiliser, Hydrogenation, Methanol, Hydrocracking, Desulphurisation
B	Shipping*, Non-Road Mobile Machinery, Chemical feedstock, Steel, Long-term storage
C	Long-haul aviation*, Coastal and river vessels, Remote trains, Vintage vehicles*, Local CO2 remediation
D	Medium-haul aviation*, Long distance trucks and coaches, High-temperature industrial heat, Generators
E	Short-haul aviation, Local ferries, Commercial heating, Island grids, Clean power imports, UPS
F	Light aviation, Rural trains, Regional trucks, Mid/Low-temperature industrial heat, Domestic heating
G	Metro trains and buses, H2FC cars, Urban delivery, 2 and 3-wheelers, Bulk e-fuels, Power system balancing

Uncompetitive

** Most likely via ammonia or e-fuel rather than H2 gas or liquid*

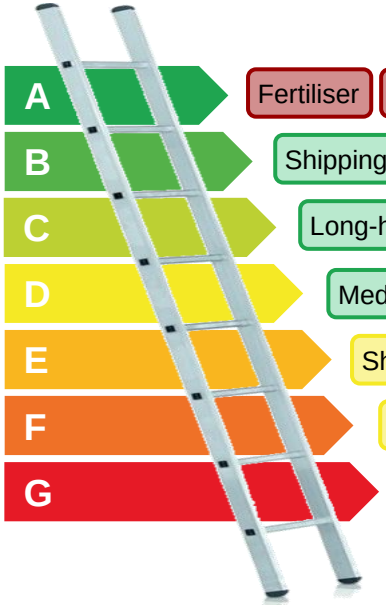
Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, 2021.Concept credit: Adrian Hiel, Energy Cities. CC-BY 3.0

Hydrogen Ladder: Competing technologies

Liebreich Associates

Unavoidable

Key: No real alternative | Electricity/batteries | Biomass/biogas | Other



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Uncompetitive

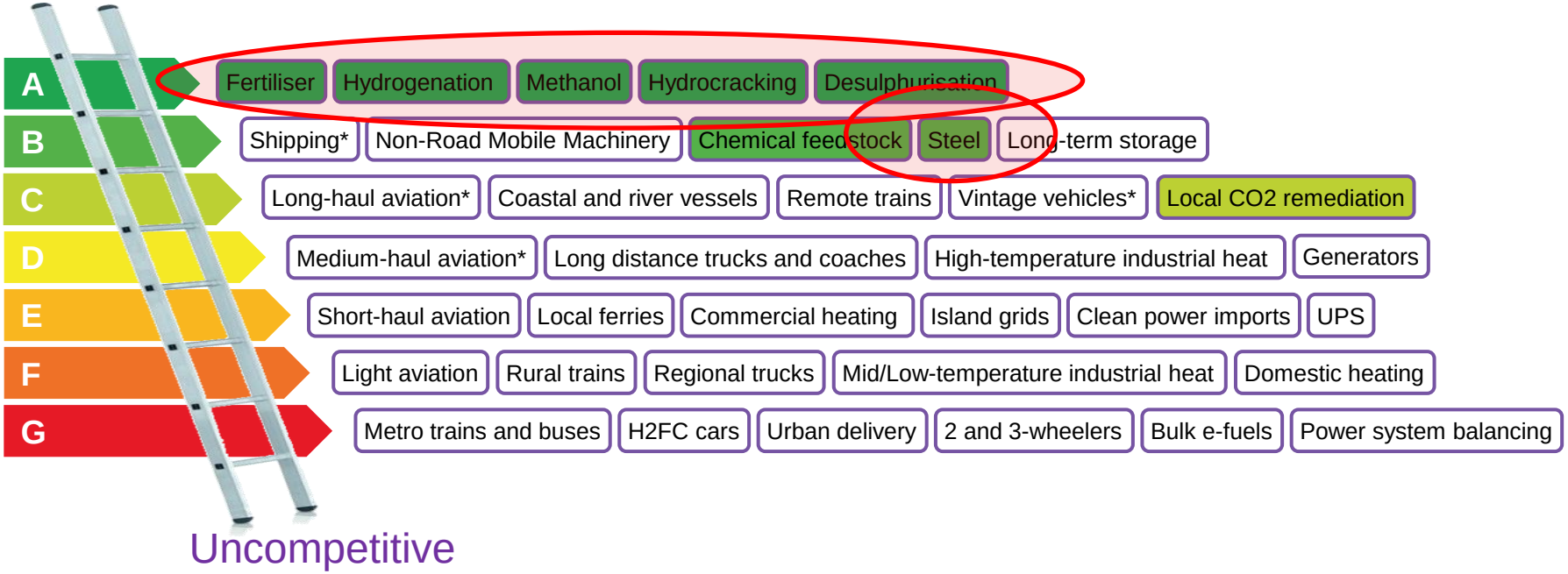
** Most likely via ammonia or e-fuel rather than H2 gas or liquid*

Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, 2021.Concept credit: Adrian Hiel, Energy Cities. *CC-BY 3.0*

Hydrogen Ladder: Chemicals & processes

Liebreich Associates

Unavoidable



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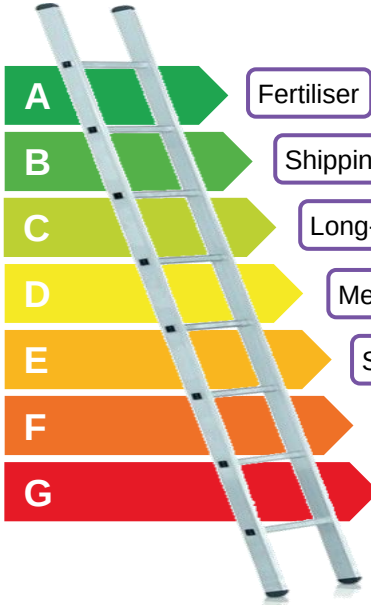
Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, 2021.Concept credit: Adrian Hiel, Energy Cities. CC-BY 3.0

Hydrogen Ladder: Land transportation

Liebreich Associates

Unavoidable



A	Fertiliser, Hydrogenation, Methanol, Hydrocracking, Desulphurisation
B	Shipping*, Non-Road Mobile Machinery, Chemical feedstock, Steel, Long-term storage
C	Long-haul aviation*, Coastal and river vessels, Remote trains, Vintage vehicles*, Local CO2 remediation
D	Medium-haul aviation*, Long distance trucks and coaches, High-temperature industrial heat, Generators
E	Short-haul aviation, Local ferries, Commercial heating, Island grids, Clean power imports, UPS
F	Light aviation, Rural trains, Regional trucks, Mid/Low-temperature industrial heat, Domestic heating
G	Metro trains and buses, H2FC cars, Urban delivery, 2 and 3-wheelers, Bulk e-fuels, Power system balancing

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Hydrogen fuel cell vs battery electric cars

Liebreich Associates

	Tesla Model 3 Long Range AWD	Toyota Mirai 2
Number of seats	5	5

Images: Tesla; Toyota; Source: Liebreich Associates

Hydrogen fuel cell vs battery electric cars

Liebreich Associates

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Range	353 miles	402 miles
Refuel time, petrol station	250 miles (10%-80%): 20 minutes	402 miles: 5 minutes

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Acceleration 0-60mph, top speed	4.2 seconds, 145 mph	9.0 seconds, 111mph
Refuel time, home, office, mall	< 1 minute to plug in	Not possible
Drive train moving parts	17	> 200

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Wind-to-wheel efficiency >>>	> 61%	< 32 %

Images: Tesla; Toyota; Source: Liebreich Associates

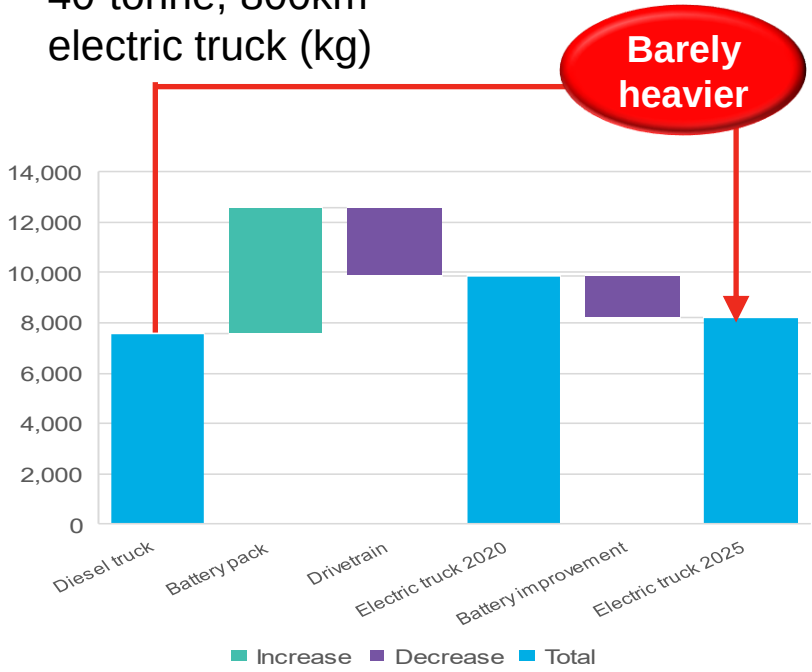
Net zero emission heavy trucks and buses eg 40-tonne truck

Liebreich Associates

Hydrogen fuel cells…

or battery electric?

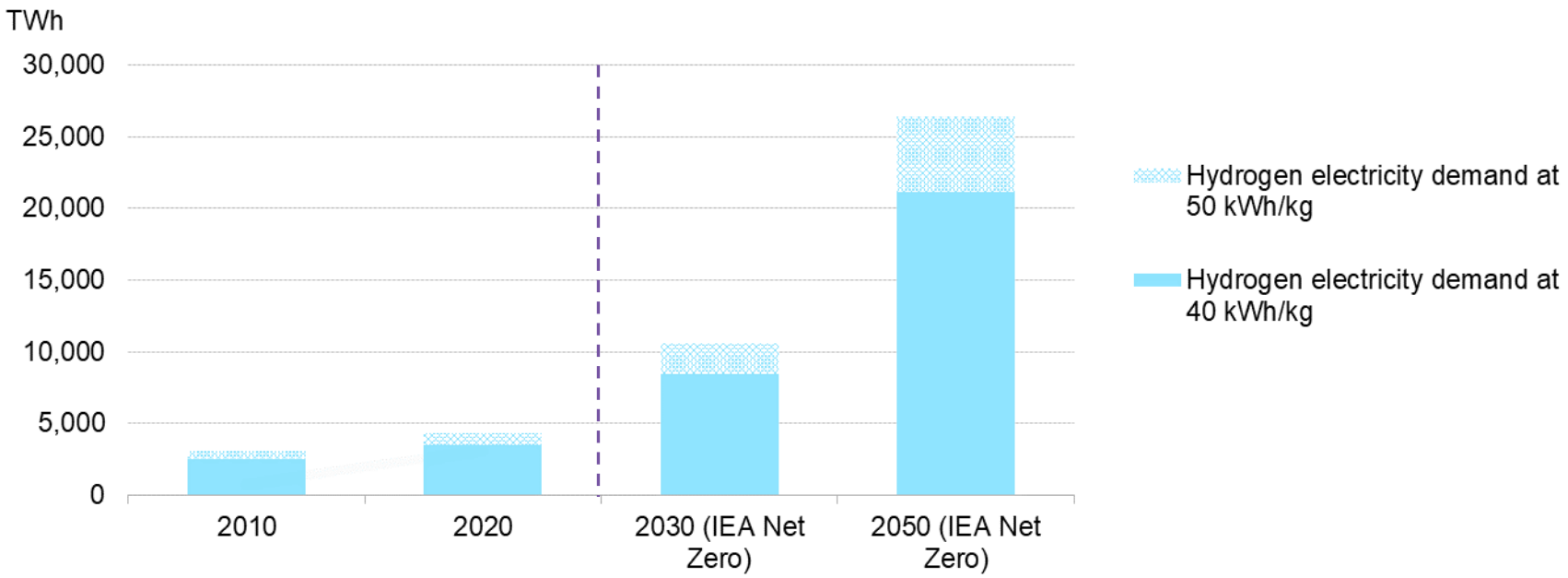
40-tonne, 800km electric truck (kg)



Images: Hyundai; Tesla; Scania

Green hydrogen electricity demand

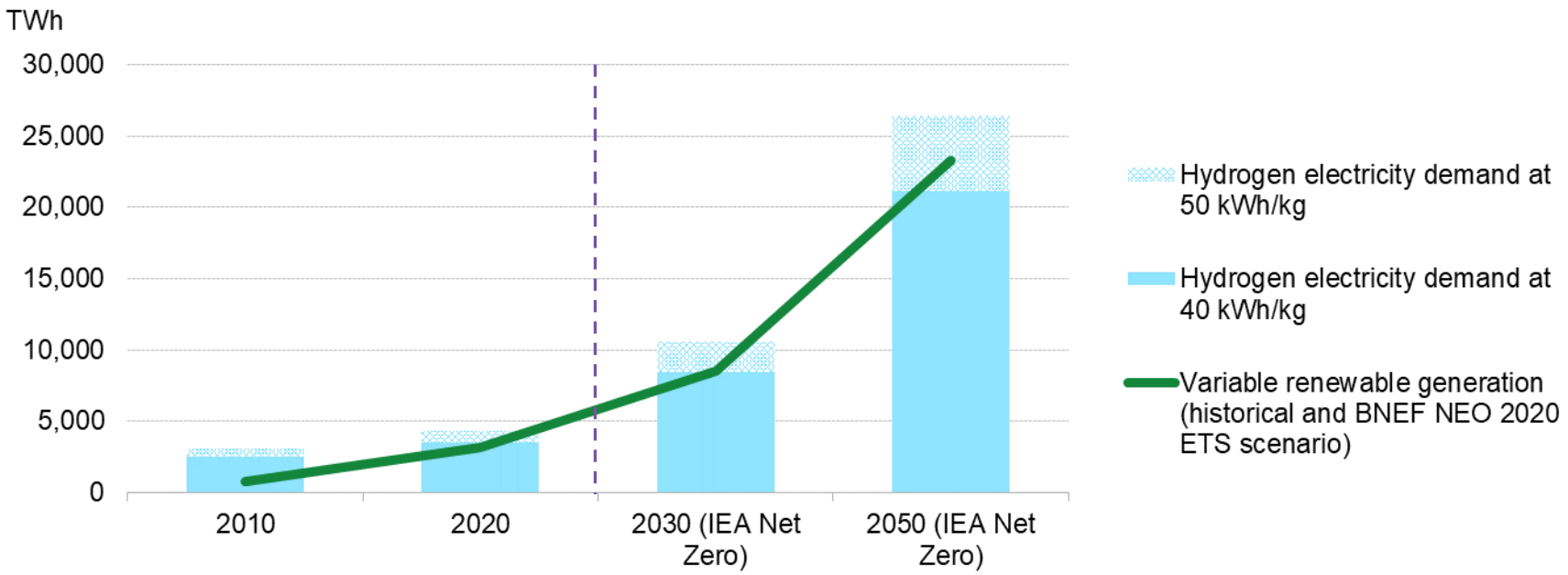
Liebreich Associates



Source: Liebreich Associates, BP, EIA, IEA Net Zero Report

Green hydrogen electricity demand

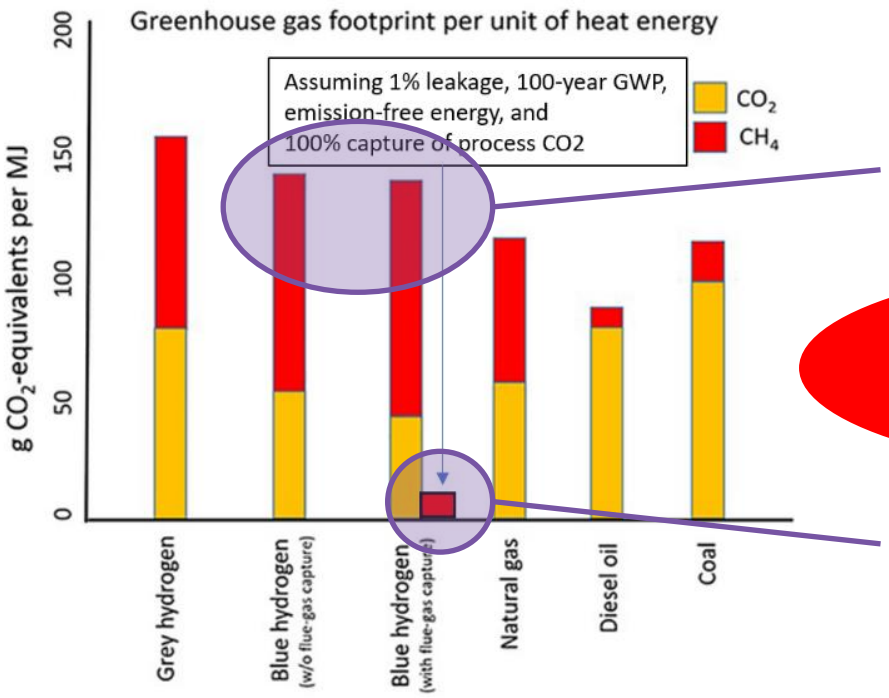
Liebreich Associates



Source: Liebreich Associates, BP, EIA, IEA Net Zero Report

Can blue hydrogen be considered clean?

Liebreich Associates



Professors Jacobson & Howarth

Challenge
CO2 capture: near 100%
Methane leaks: near zero

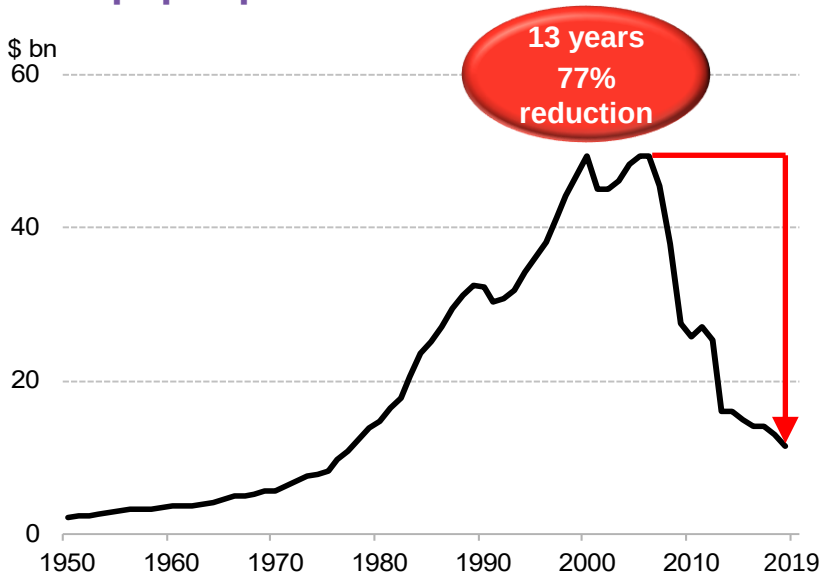
Professor Caldeira and others

Source: Ken Caldeira, Matteo Romano

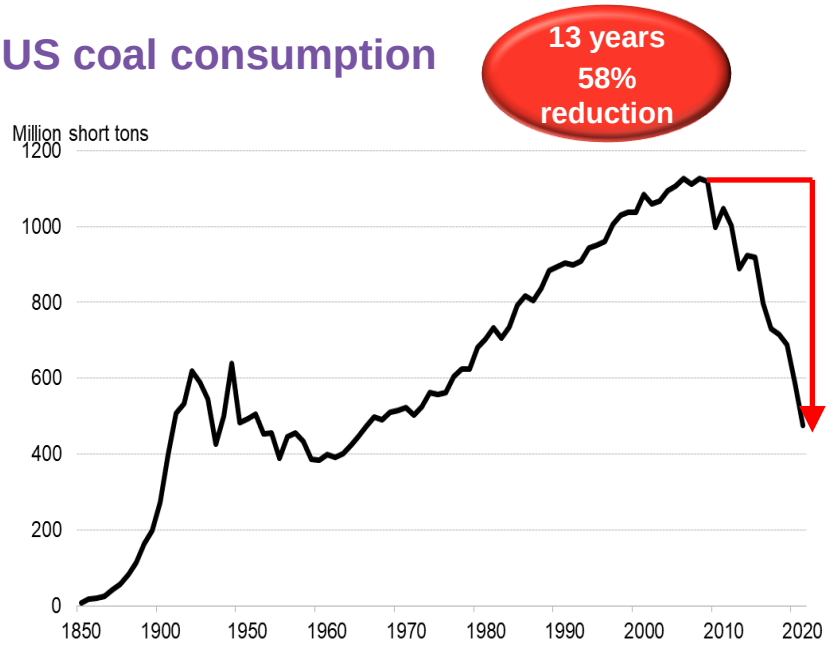
Speed of transitions

Liebreich Associates

Newspaper print ad revenue



US coal consumption



Source: US Census, PEW Research, EIA, Liebreich Associates

Timing is everything

Liebreich Associates

"Lost my ass on wind energy. Not wrong. Just early."

T. Boone Pickens
Chairman, BP Capital Management
June 2019

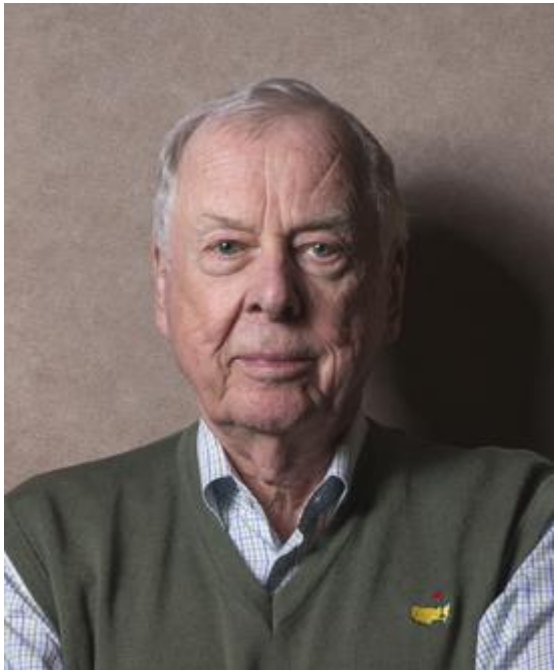


Image: Boonepickens.com

Liebreich Associates

Thanks!

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