DRIVING LOW-CARBON INNOVATION FOR CLIMATE NEUTRALITY

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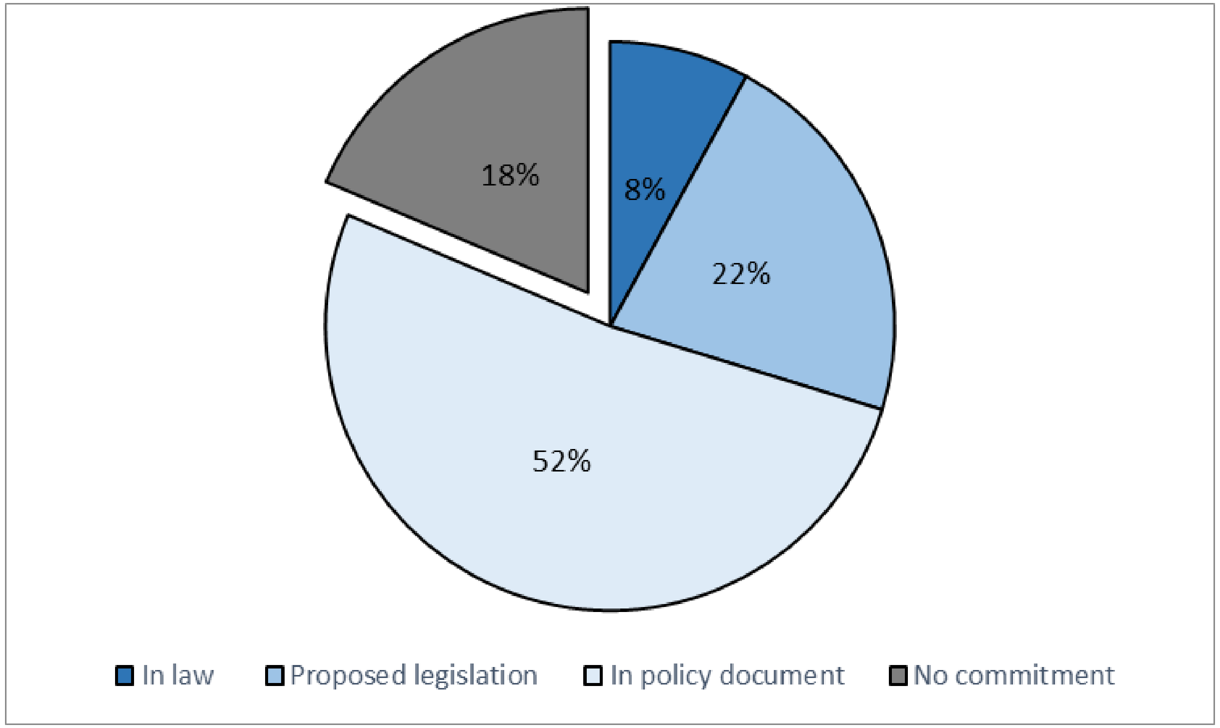
OECD
BETTER POLICIES FOR BETTER LIVES

BACKGROUND

An ambitious climate agenda across OECD and non-OECD countries

- Over 80% of the world's economy has adopted carbon neutrality goals by 2050
- 2030 targets:
  – EU: -55% wrt 1990
  – US: -50% wrt 2005

Share of global economy that announced net-zero CO_2 or GHG emissions by mid-century



Source: Own calculations based on the share of global GDP represented by the countries that commit according to the Net Zero Tracker (https://eciu.net/netzerotracker). Share of global GDP is calculated based on GDP in 2017 taken from World Bank national accounts data and OECD National Accounts data (2021).

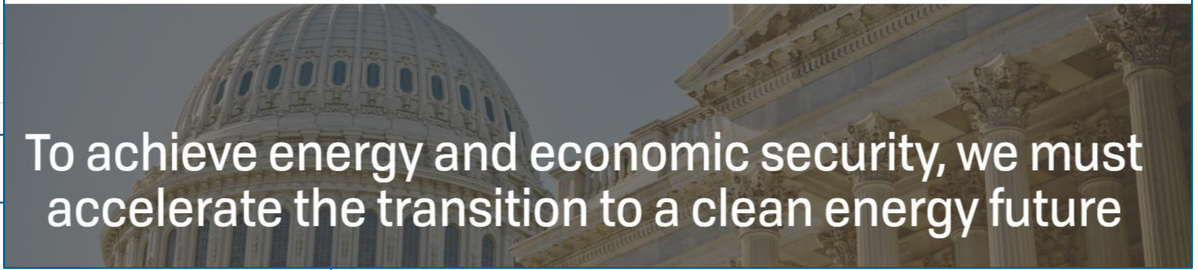
The need to reduce fossil fuel dependence could boost decarbonization targets

ENVIRONMENT

Will war fast-track the energy transition?

▼ IN FOCUS: UKRAINE

Ceres



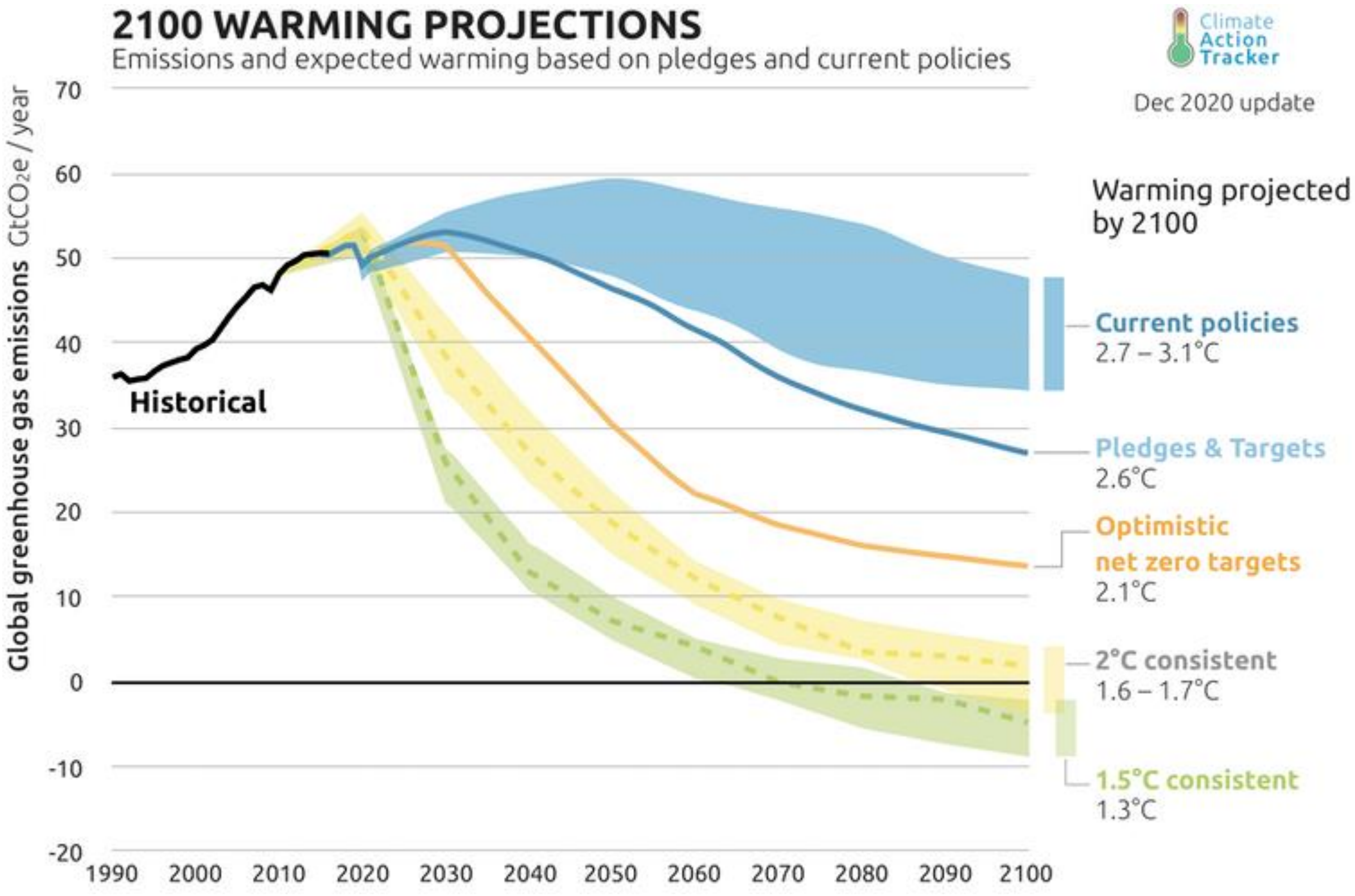
European Commission

Home › Strategy › Priorities 2019-2024 › A European Green Deal › REPowerEU: affordable, secure and sustainable energy for Europe

REPowerEU: affordable, secure and sustainable energy for Europe

How we reach zero-carbon energy independence

Emissions are not on track - climate policies need to become much more ambitious

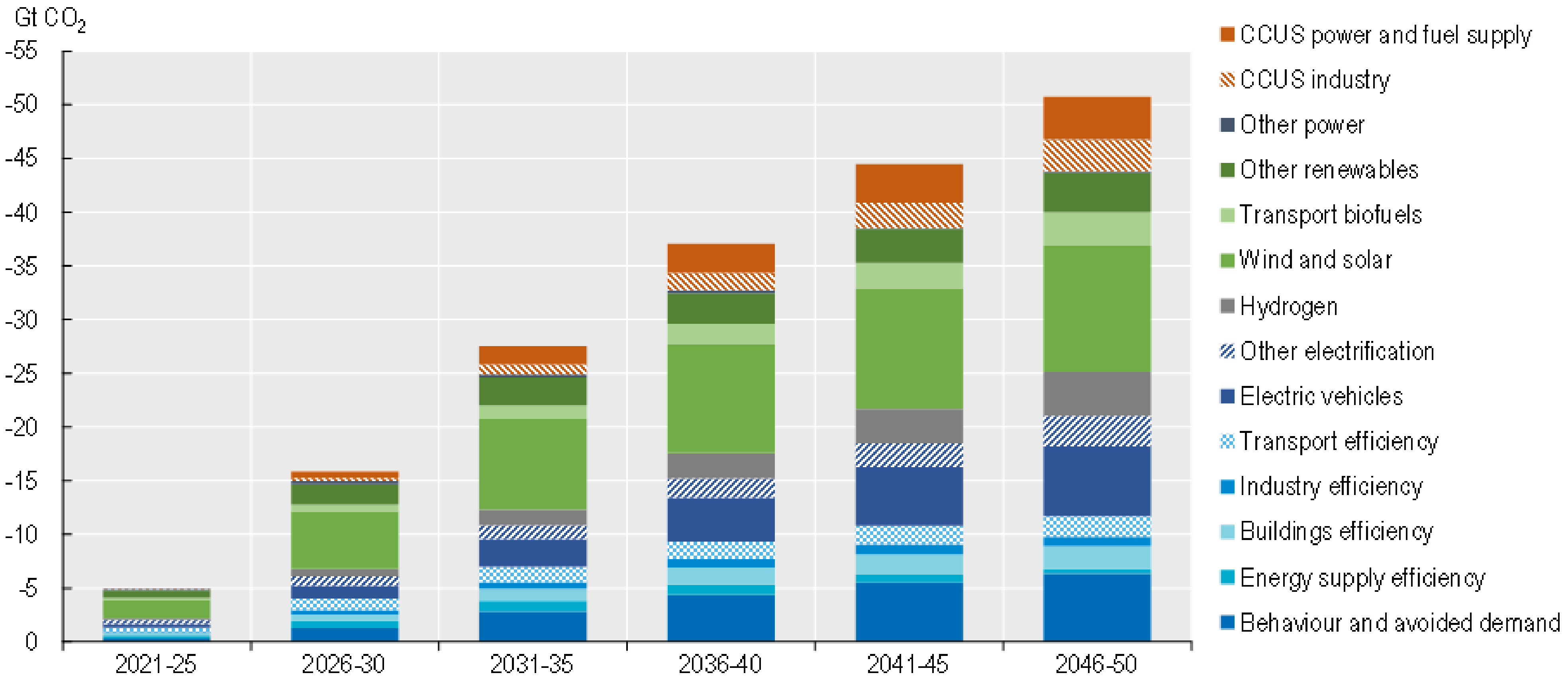


Source: Carbon Action Tracker

INNOVATION IS KEY FOR NET ZERO

Climate neutrality requires a system-wide technological shift

Sources of CO_2 emission reductions in IEA's net-zero scenario



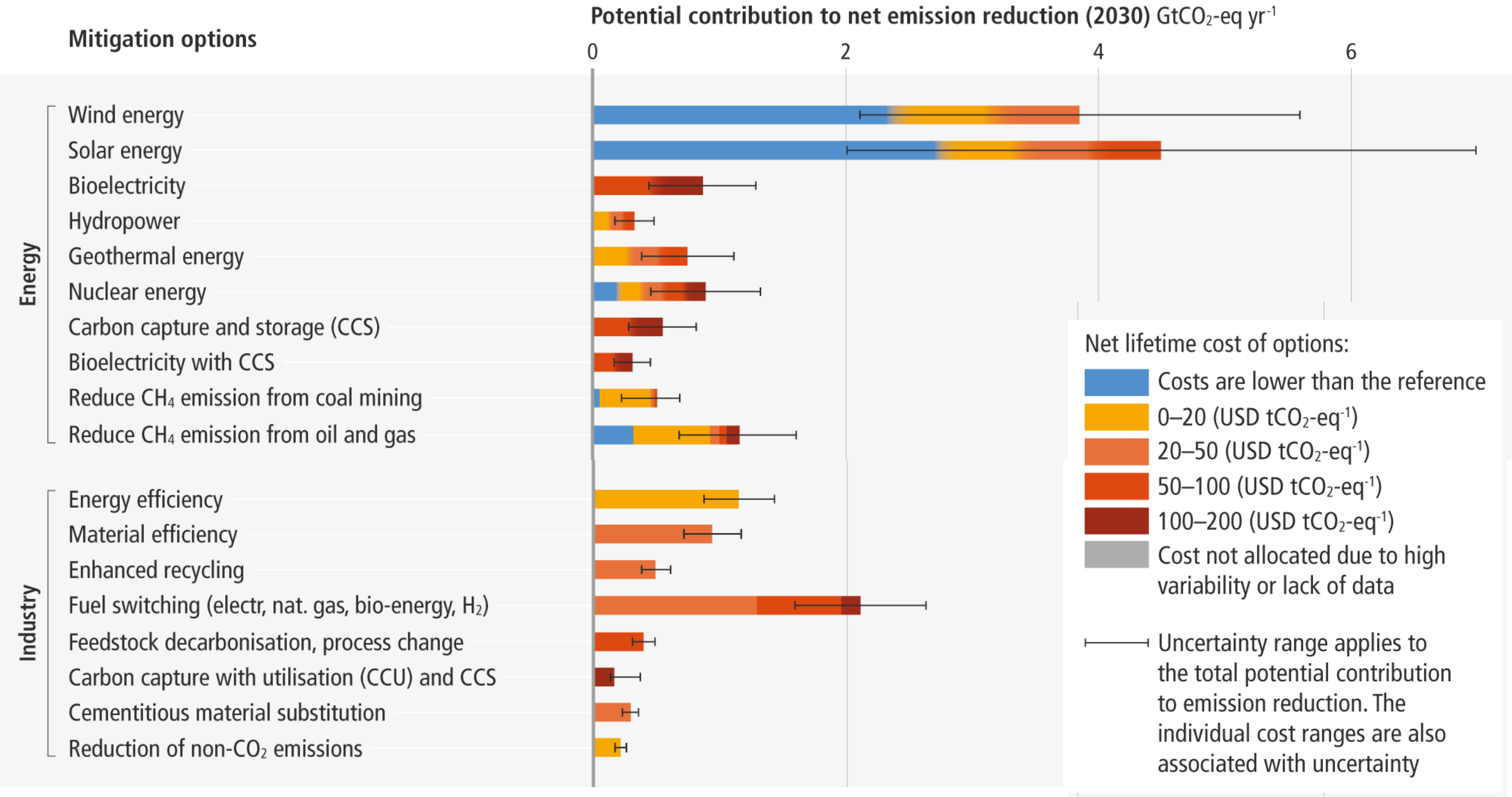
Source: IEA 2021

Innovation is needed

- Reduce the cost of existing technologies
- Develop early-stage technologies further and discover potential breakthroughs

- Both in low-carbon technologies and enabling technologies (eg digital)

Mitigation costs are still too high in many technologies & sectors

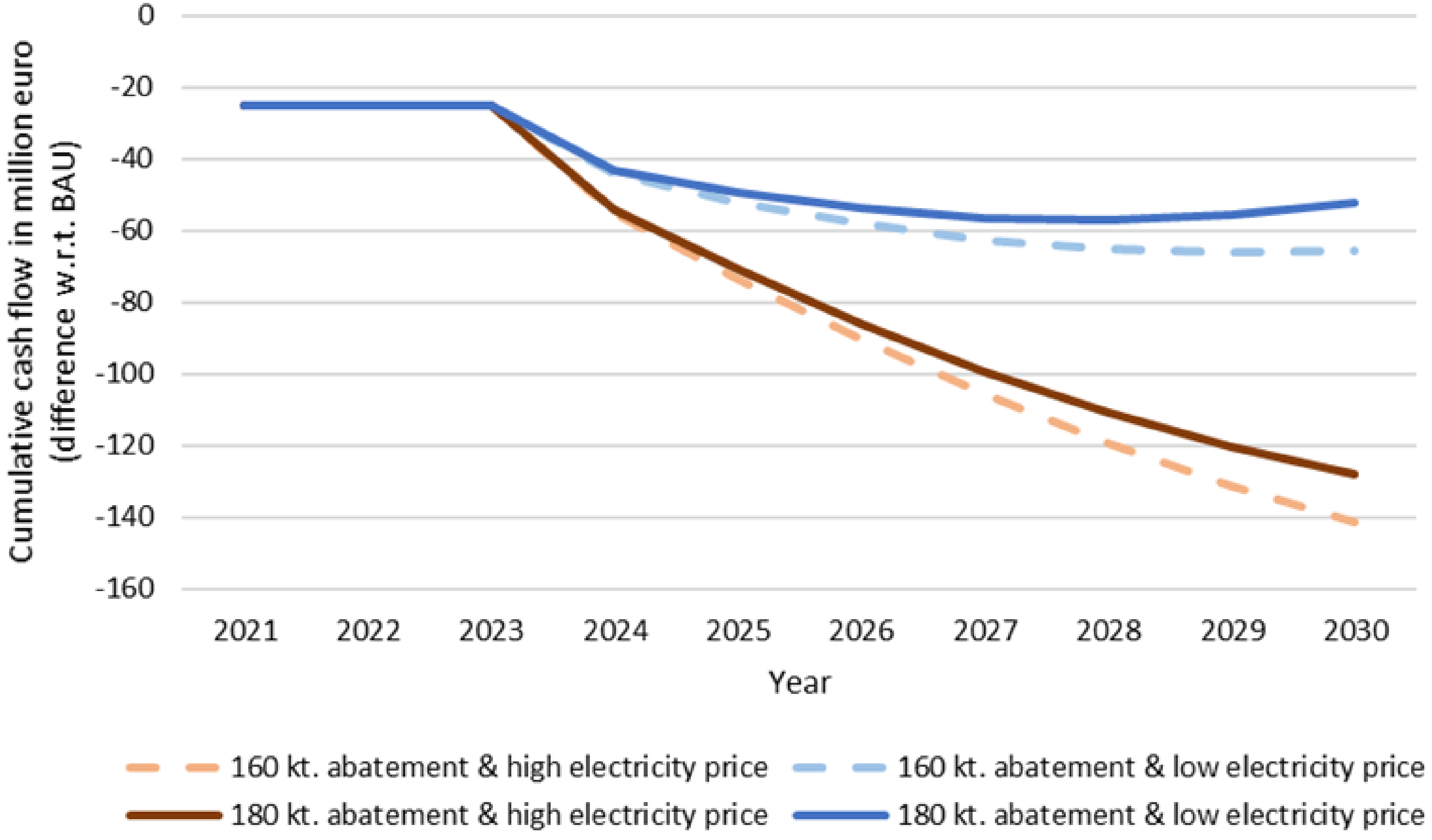


Source: IPCC 2022, Sixth Assessment Report, Working Group III – Mitigation of climate change

For example, green hydrogen is not competitive with fossil-based alternatives (even with high carbon prices)

- Producing hydrogen from electrolysis with renewable electricity for ammonia production is still 3 times more expensive than from natural gas
  – Even with carbon price savings and adoption subsidies
- Cost reductions are needed

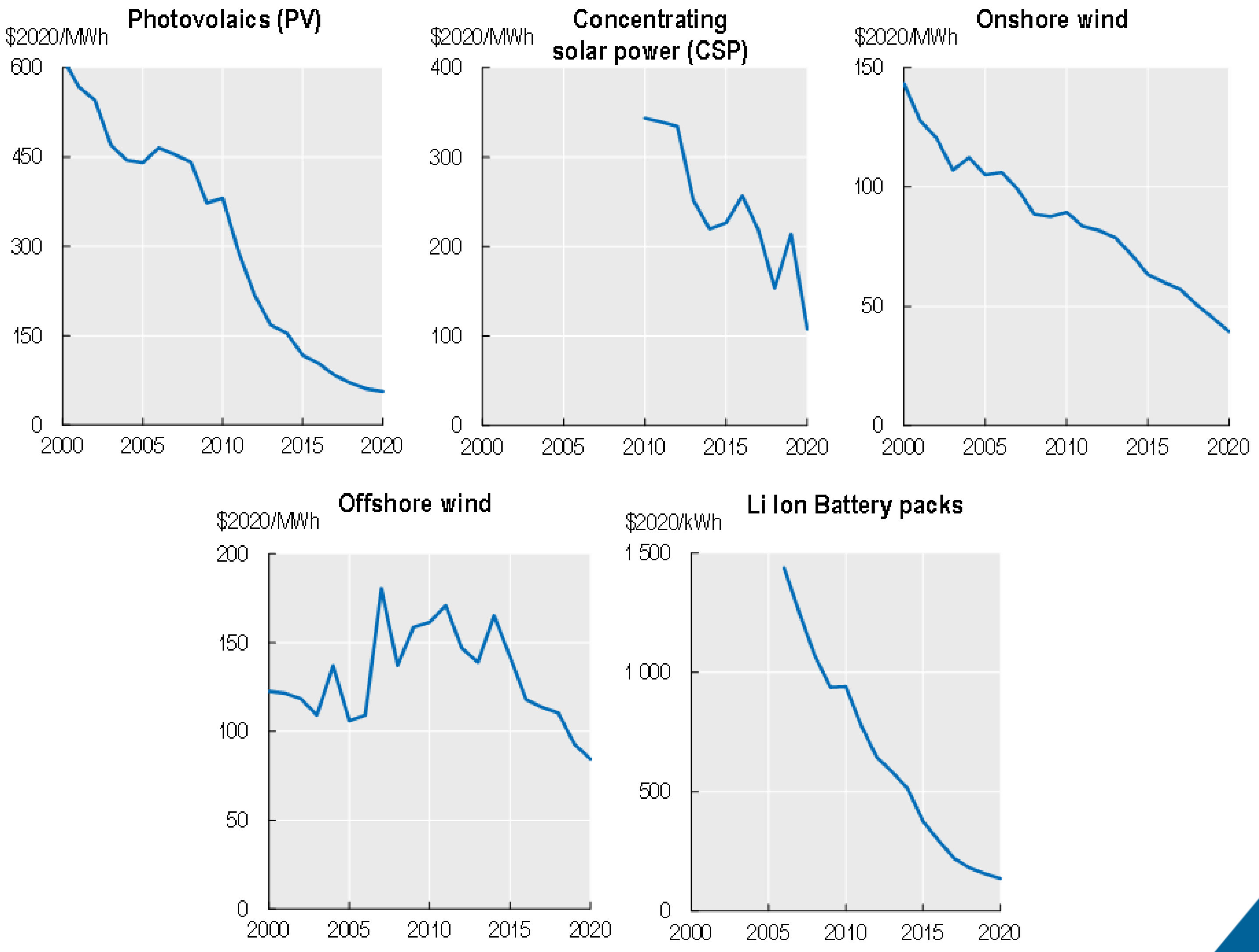
Green hydrogen electrolyser cumulated cash flows for different scenarios



Source: Cammeraat, E., A. Dechezleprêtre and G. Lalanne (2022), "Innovation and industrial policies for green hydrogen", OECD Science, Technology and Industry Policy Papers, No. 125, OECD Publishing, Paris

Continuous innovation is key to reducing the costs of low-carbon technologies

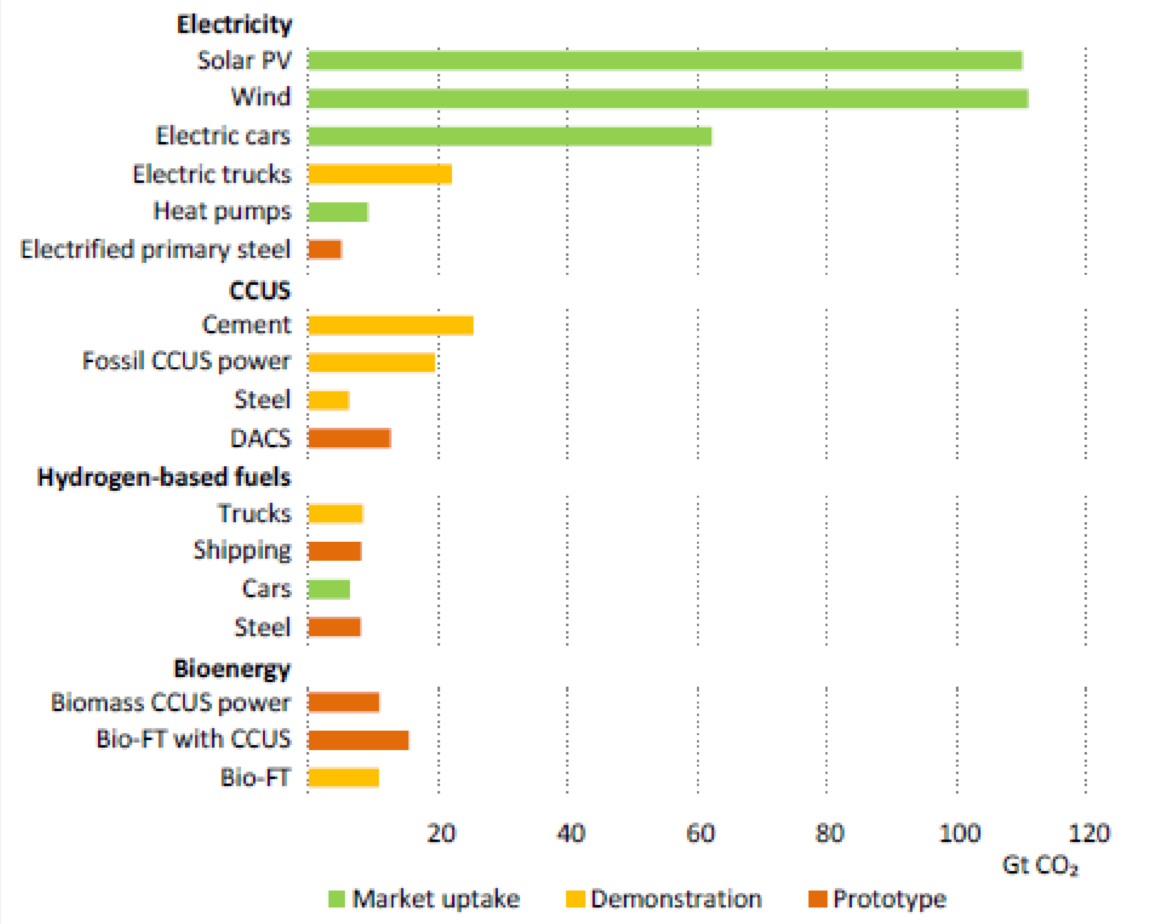
Declining renewable energy and battery costs since 2010



Source: IRENA 2021, IPCC 2022.

2030 objectives can be reached with existing technologies, but not 2050 targets

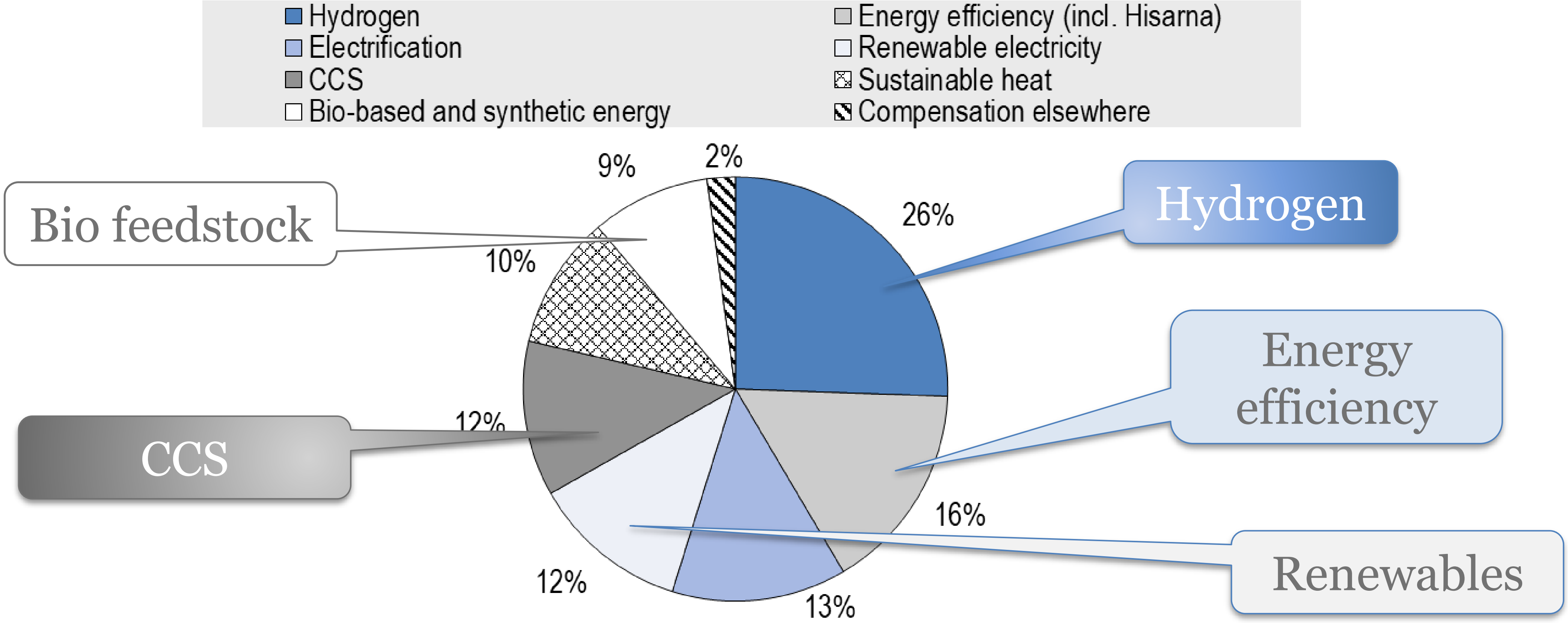
Figure 2.32 ▷ Cumulative CO_2 emissions reductions for selected technologies by maturity category in the NZE



- In the IEA's net-zero scenario, most of the global reductions in CO_2 emissions through **2030** come from technologies readily available today
- But almost half the reductions in **2050** will have to come from technologies that are currently at the demonstration or prototype phase

Decarbonisation requires emerging technologies and breakthroughs: e.g. in Dutch industry

Role of various technologies in emission reductions in the Dutch manufacturing sector, 2015-50



Source: OECD, Policies for a climate-neutral industry – lessons from the Netherlands, https://www.oecd.org/netherlands/policies-for-a-climate-neutral-industry-a3a1f953-en.htm

ARE WE MOVING FAST ENOUGH?

Insights from patent data

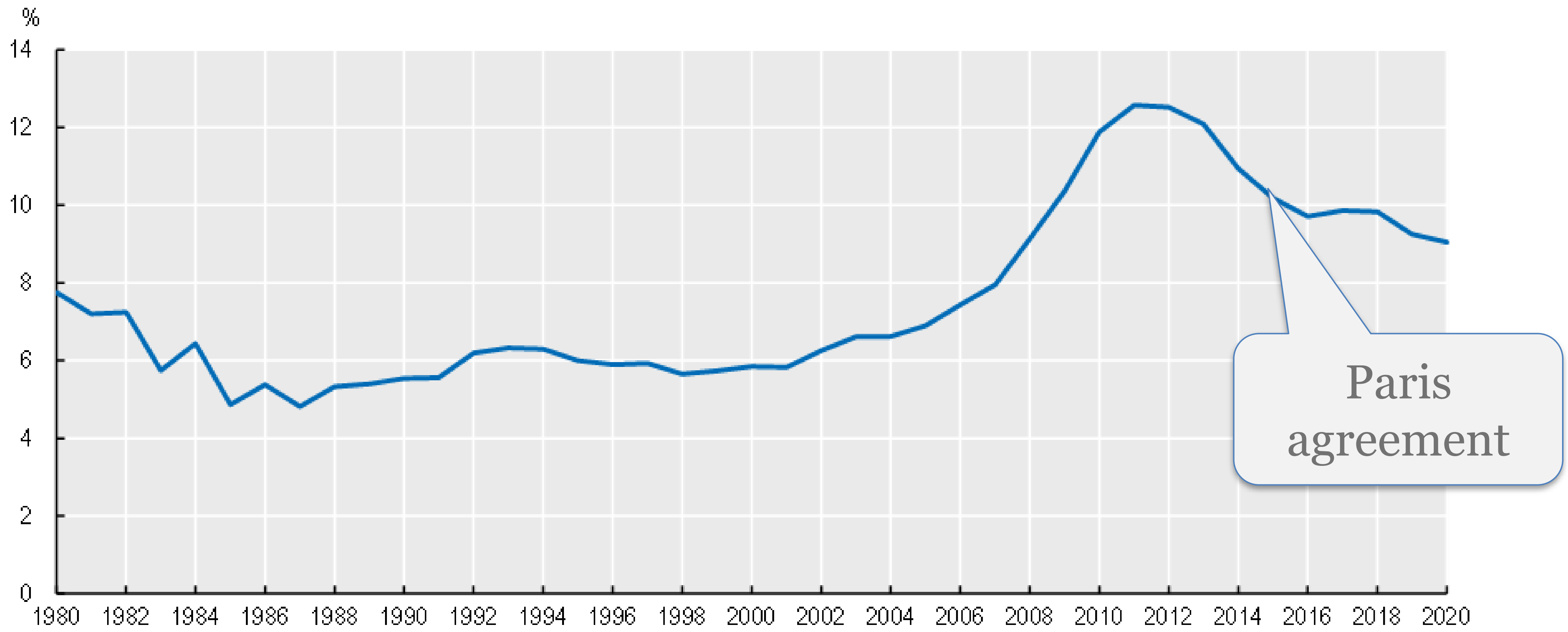
- World Patent Statistical Database (PATSTAT) maintained by European Patent Office
- 100 million patents filed in >100 patent offices since 19^{th} century
- “Tags” for climate change mitigation technologies

Climate change mitigation technologies available from patent data

Technology area	Technologies covered
Renewables	Biofuels; Fuel from waste; Geothermal; Hydro; Nuclear; Solar photovoltaic; Solar thermal; Wind
Combustion	Cleaner coal (combined heat and power, etc)
Other energy techs	Biofuel, fuel from waste, nuclear
GHG capture	CCS; Capture or disposal of non-CO2 GHG
Enabling technologies	Energy storage; Hydrogen; Fuel cells
Energy efficiency in production and distribution	Smart grids
Transportation	Electric vehicles; Hybrid vehicles; Fuel efficient engines; Improved vehicle design
Energy efficiency in buildings	Architecture; Heating; Insulation; Lighting
Energy efficiency in industry	Metal processing, oil refining, cement production

The pace of low-carbon innovation has slowed down

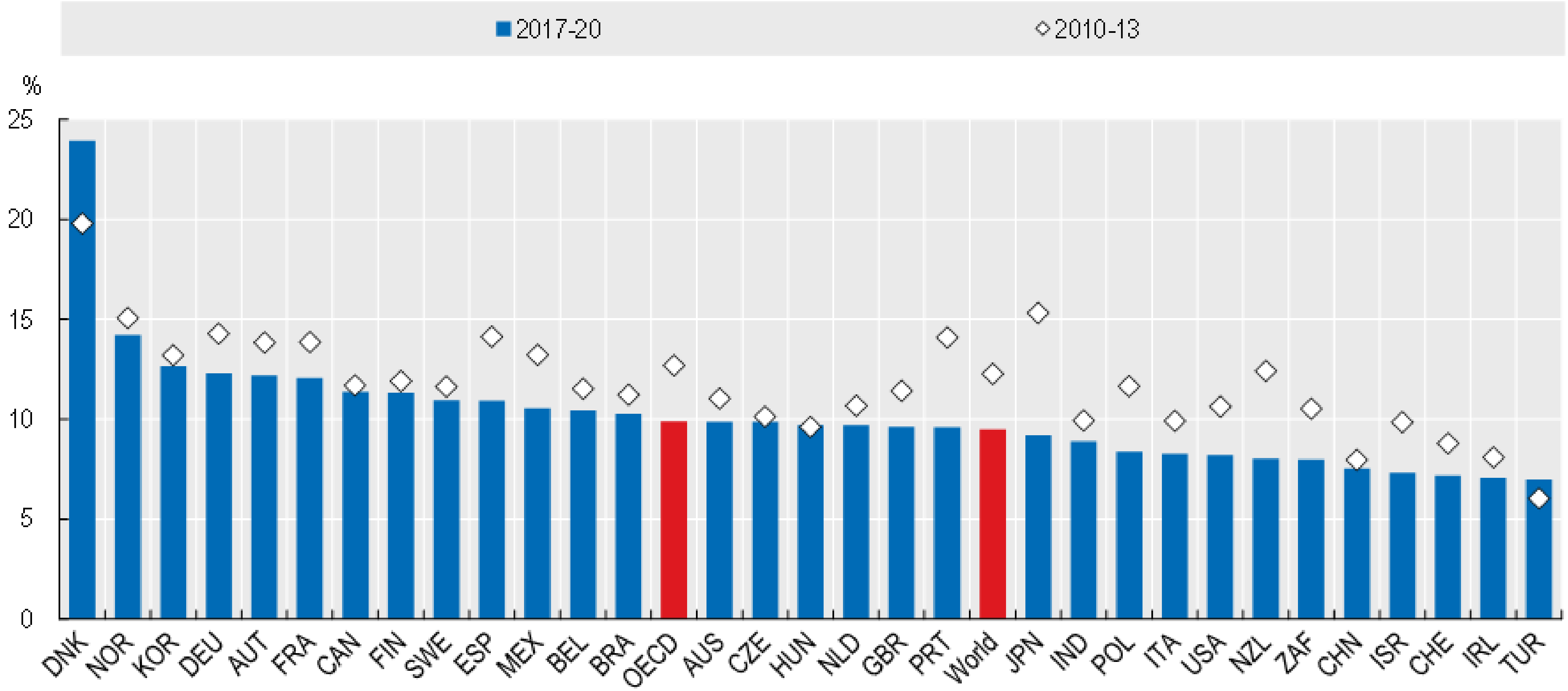
Share of climate mitigation patents in total patents, 1980-2020



Source: OECD STI MicroData Lab, Worldwide Patent Statistical Database (PATSTAT)

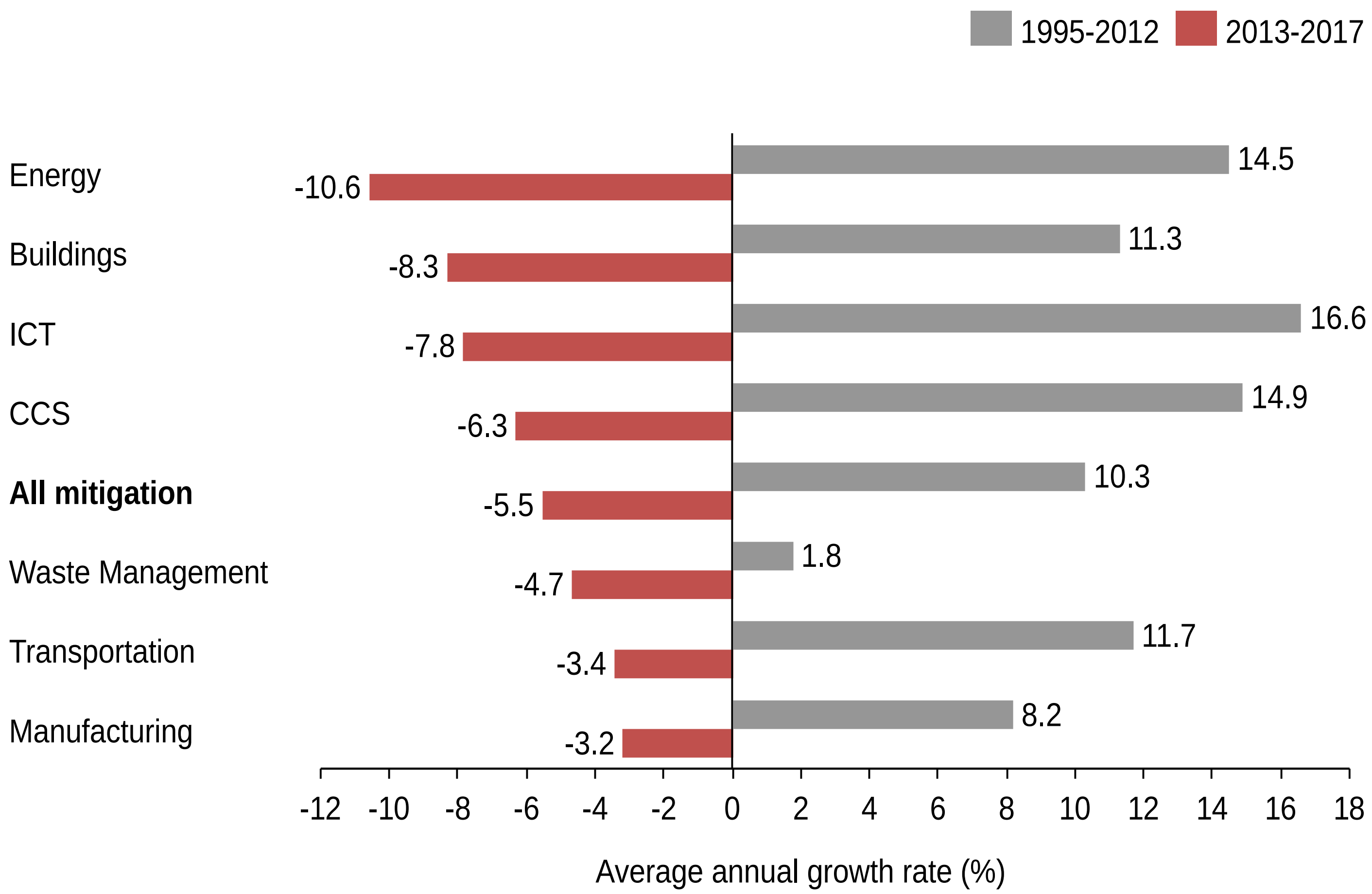
With a decrease across all major inventor countries

Climate-related technologies in the patent portfolio of countries, 2010-13 and 2017-20



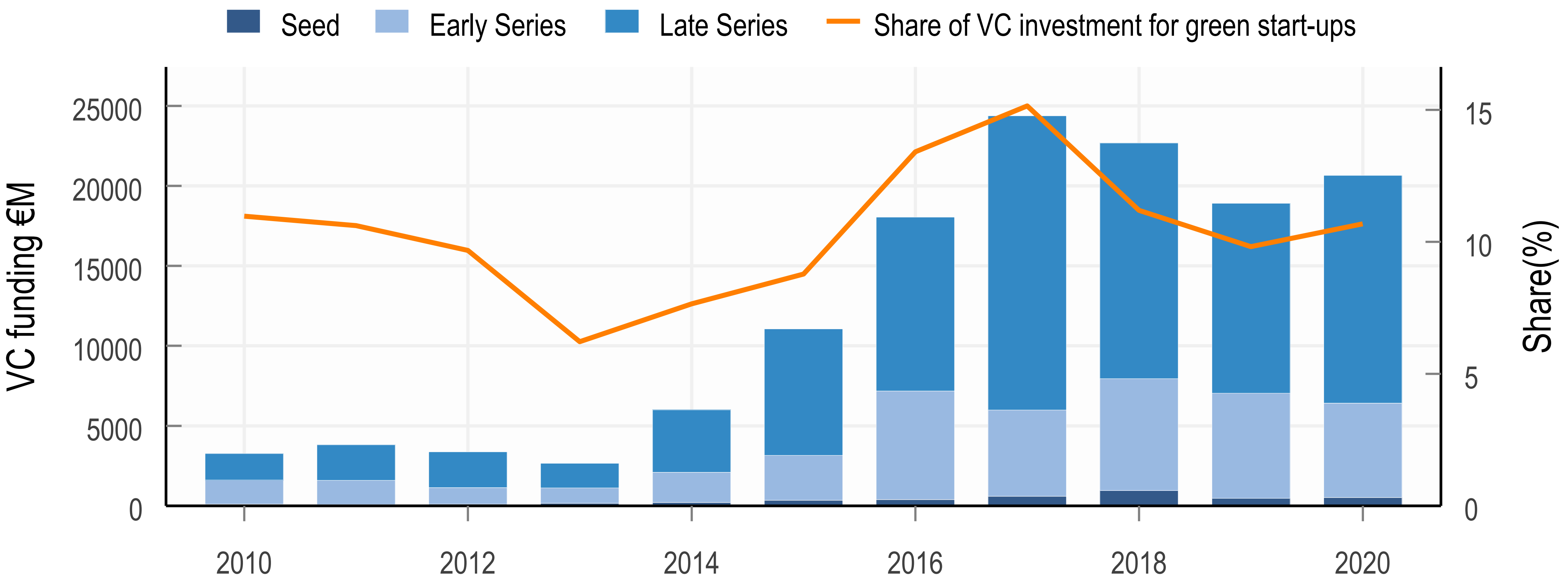
Source: OECD STI MicroData Lab, Worldwide Patent Statistical Database (PATSTAT), November 2022

And across all technology areas



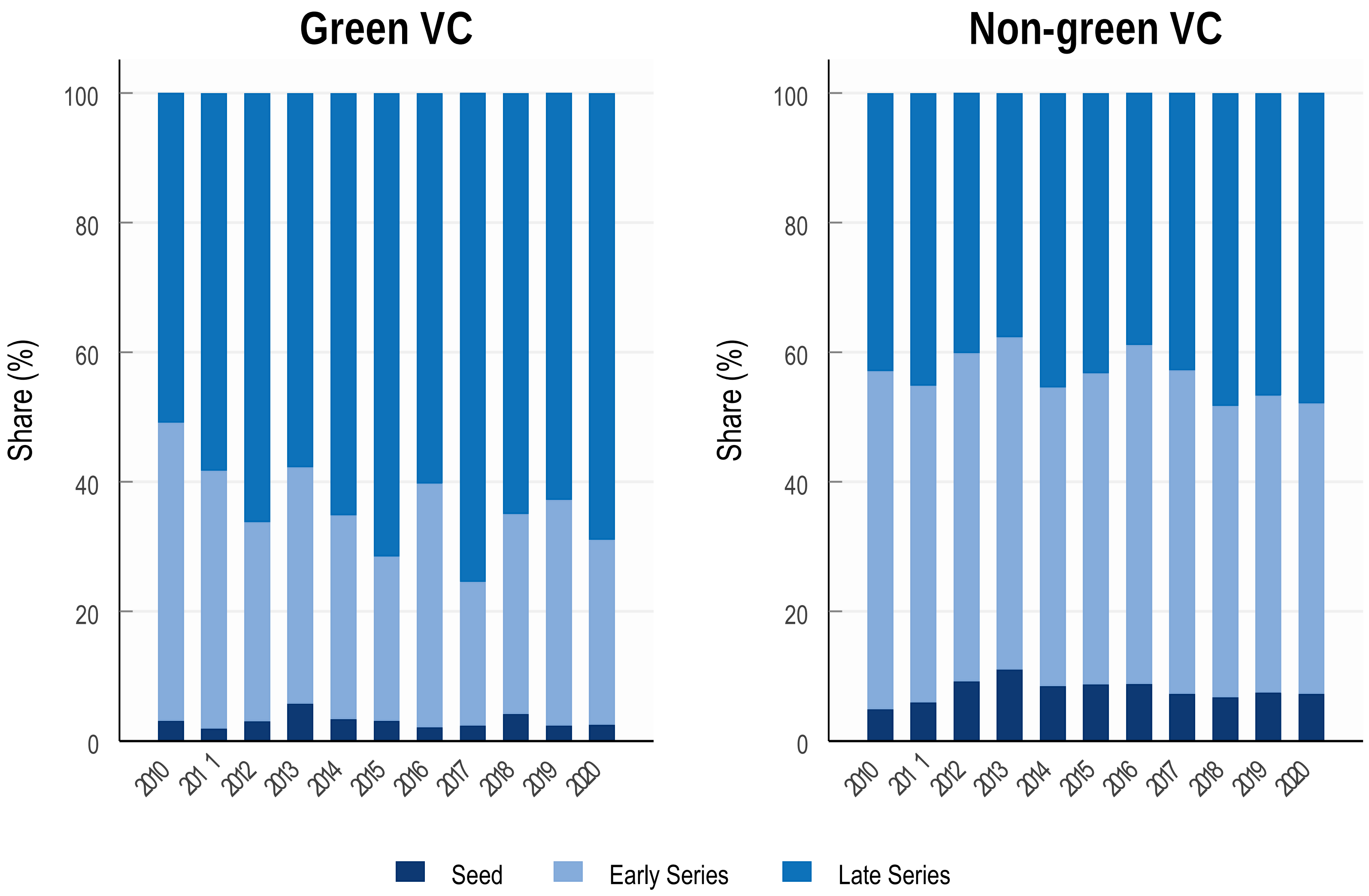
Source: Touboul et al 2021

The volume and share of green Venture Capital has decreased recently



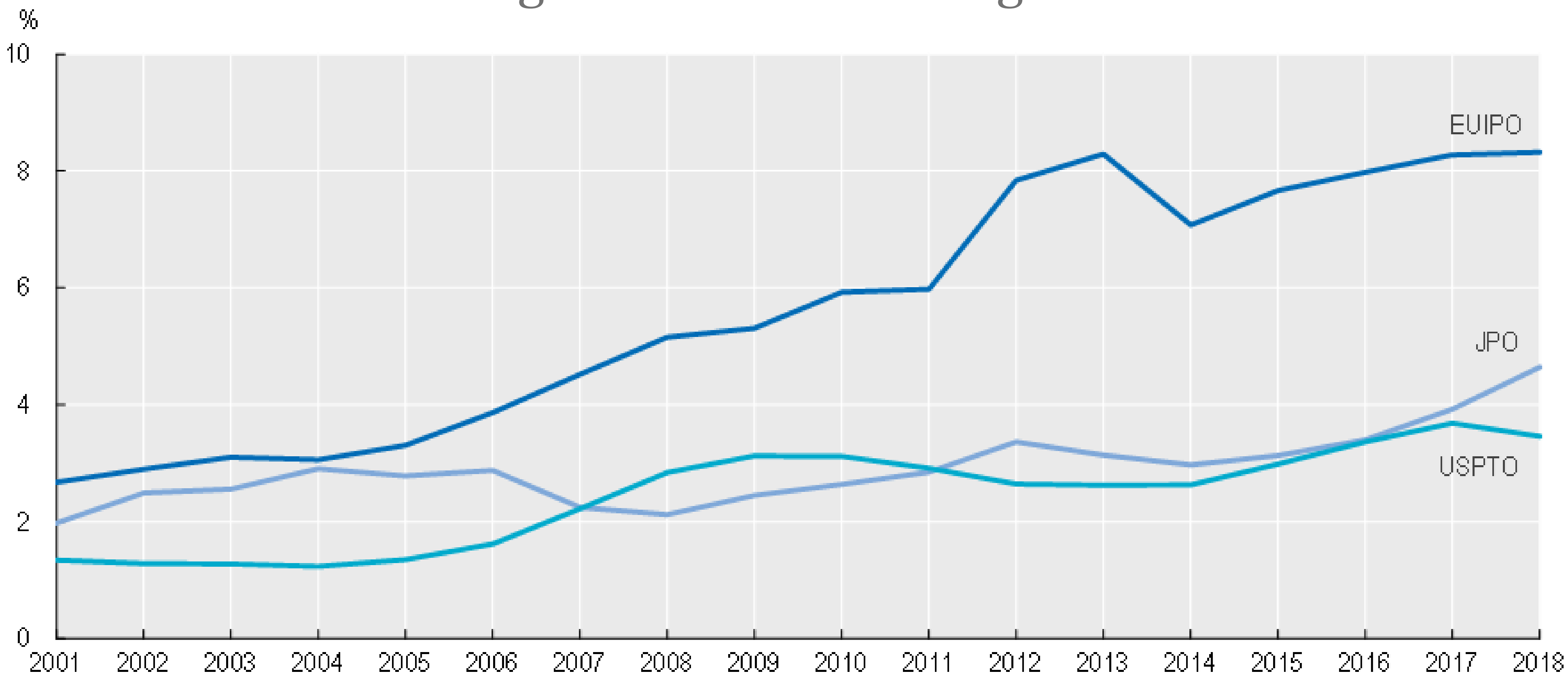
Source: OECD, based on Crunchbase and Dealroom data.

The share of seed funding is lower in green VC compared to non-green VC



The filing of climate-related trademarks is growing, suggesting focus on diffusion of existing technologies

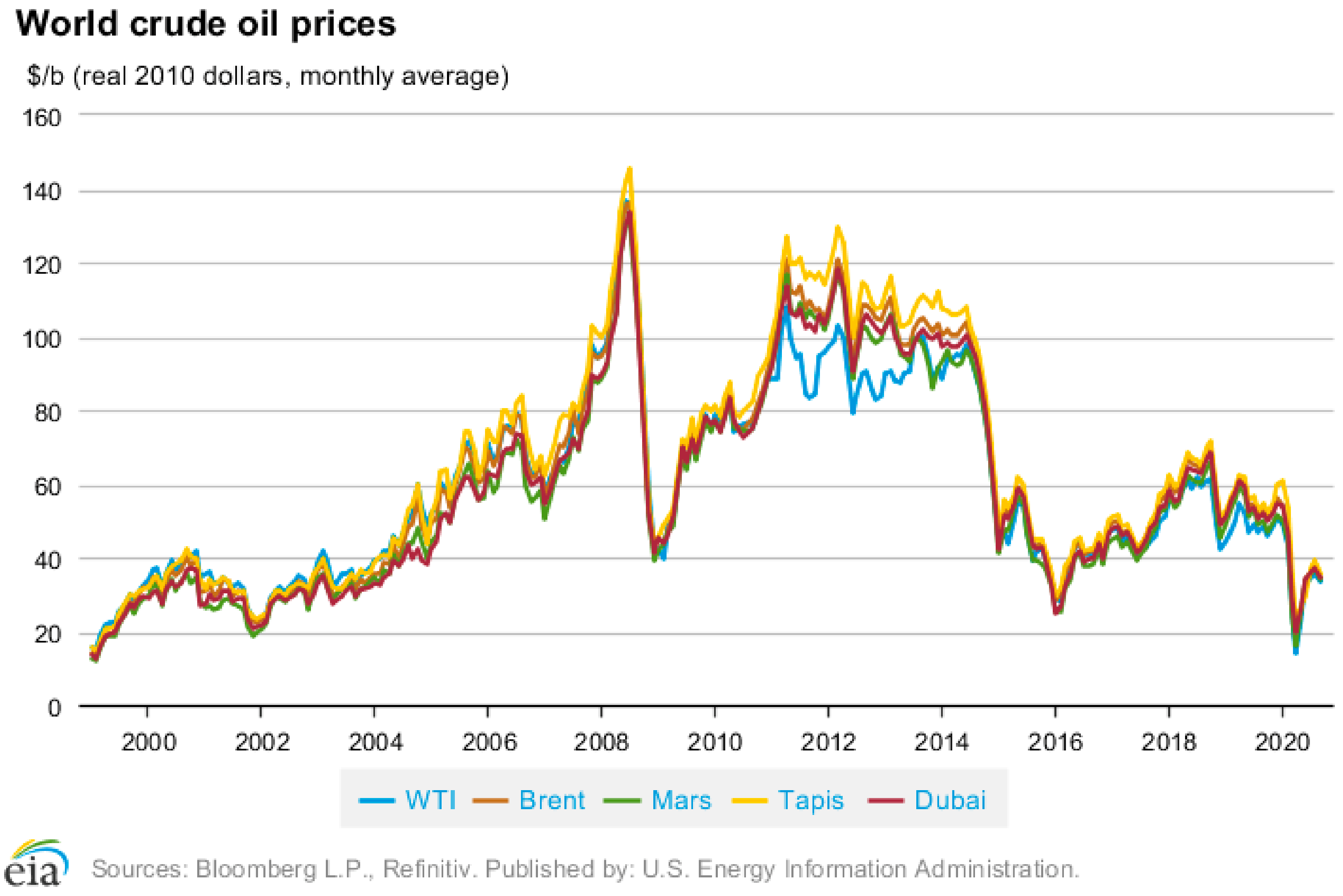
Trademark filings in climate-related goods and services



Source: OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, October 2021

WHY IS LOW-CARBON INNOVATION SLOWING DOWN?

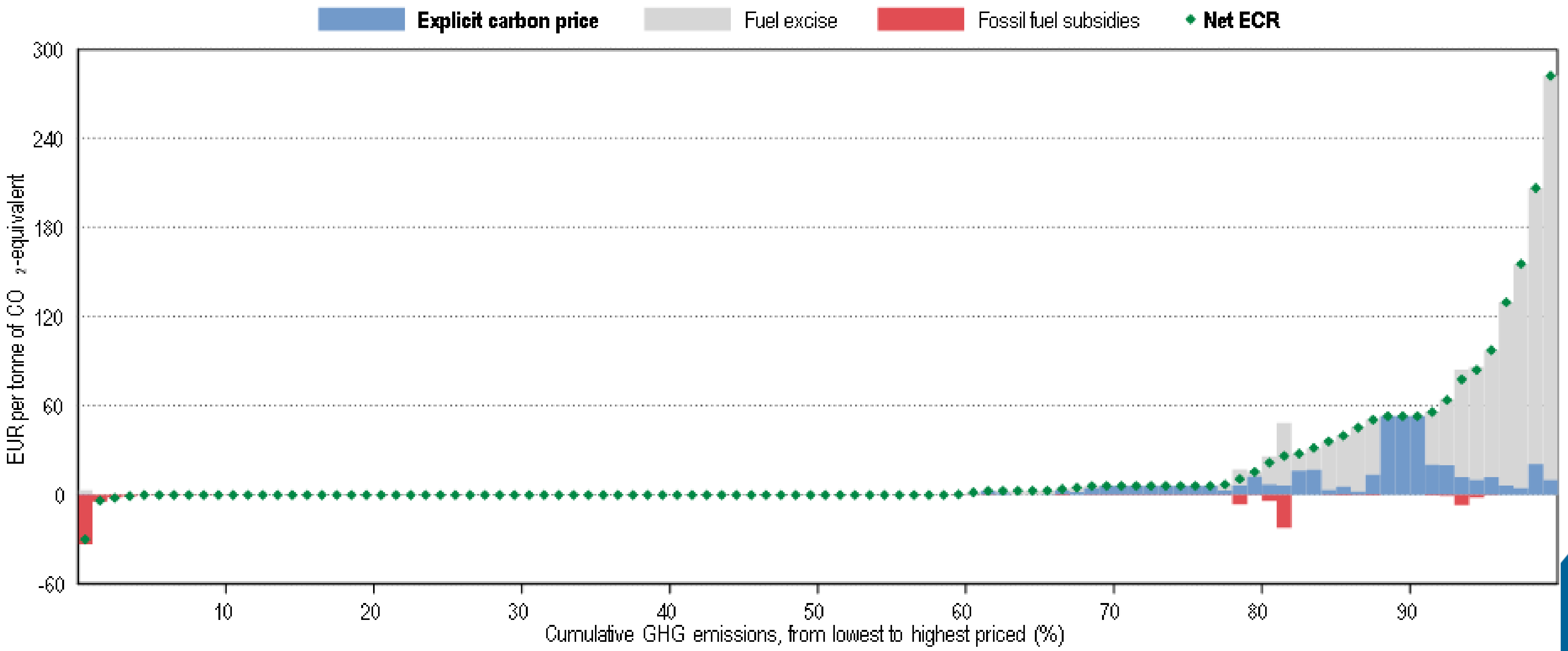
Falling energy prices (until recently)



Low carbon prices globally…

- 60% of carbon emissions not priced
- Only 10% priced at above 60 EUR/ton

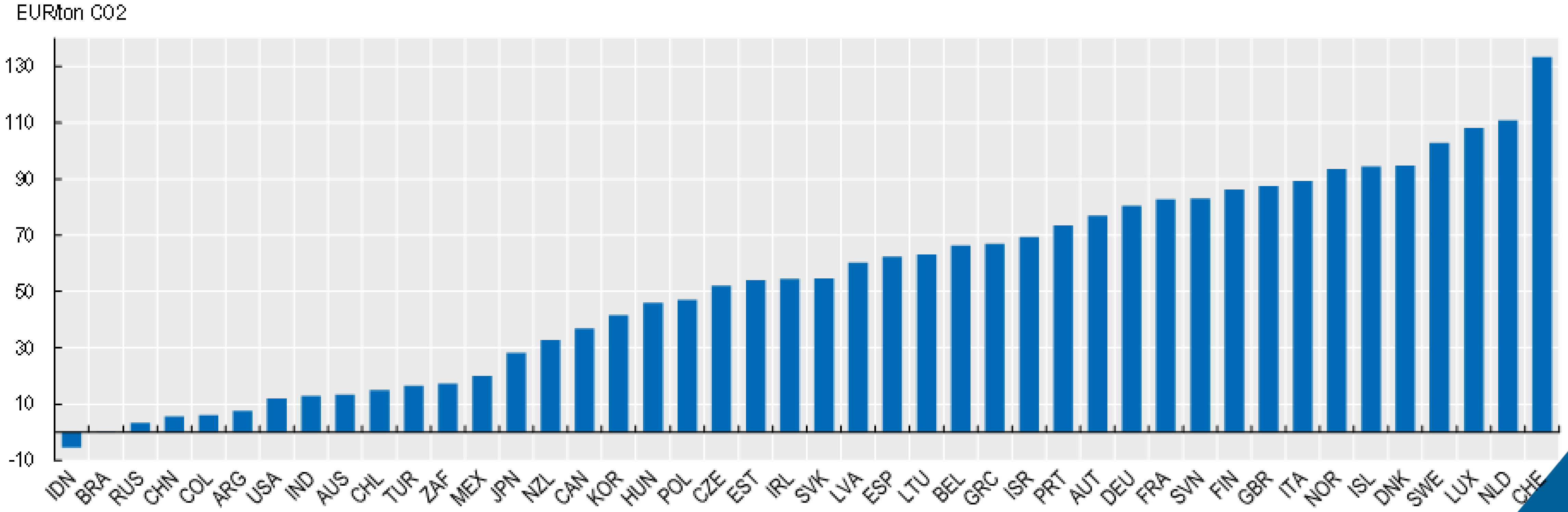
Carbon pricing in 44 OECD and G20 countries, 2021



Source: OECD Effective Carbon Rates (2021)

… and a large "carbon pricing gap" in many countries

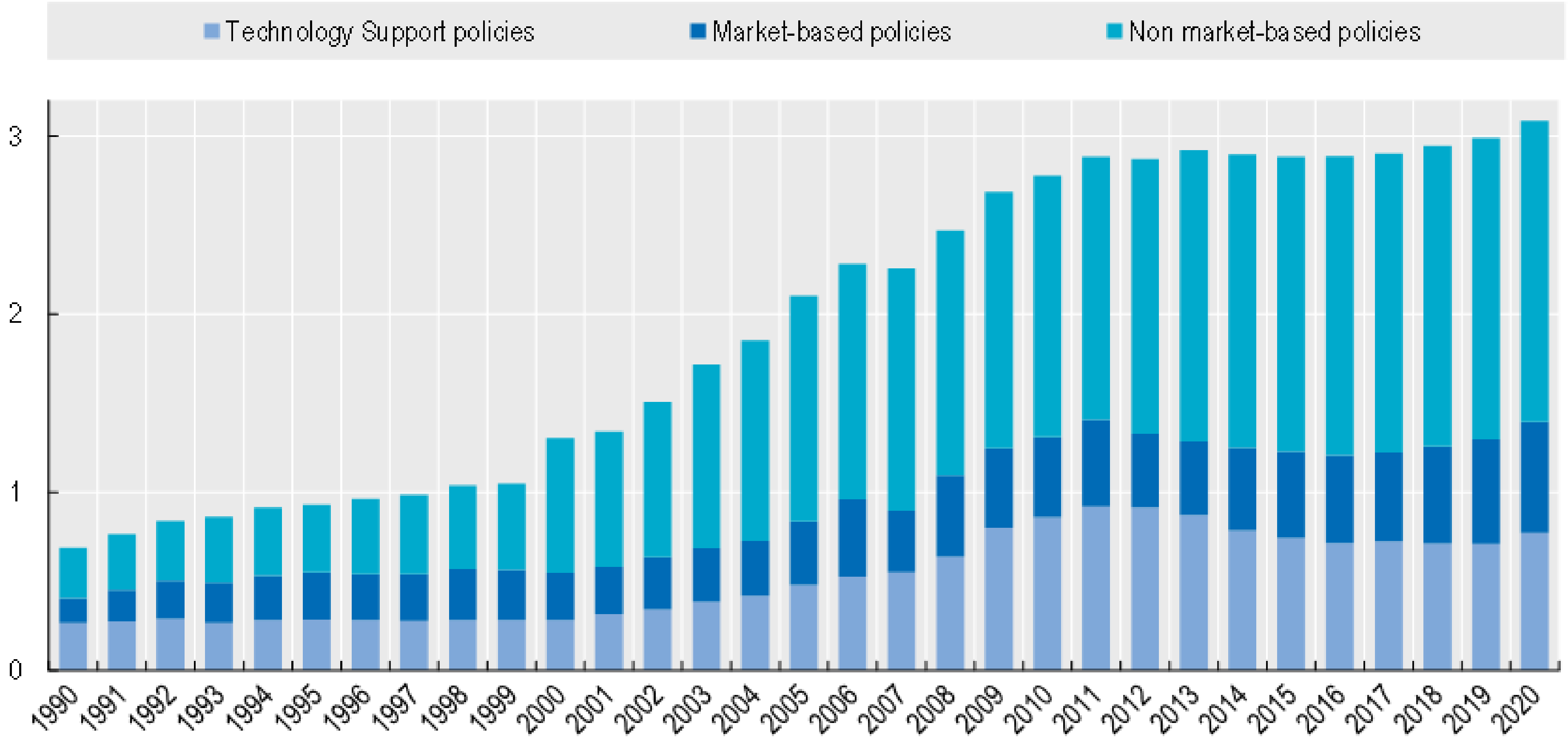
Average effective carbon prices in EUR/tCO2e, by country, 2021



Source: OECD Effective Carbon Rates (2021)

Slowdown in growth of climate policy stringency…

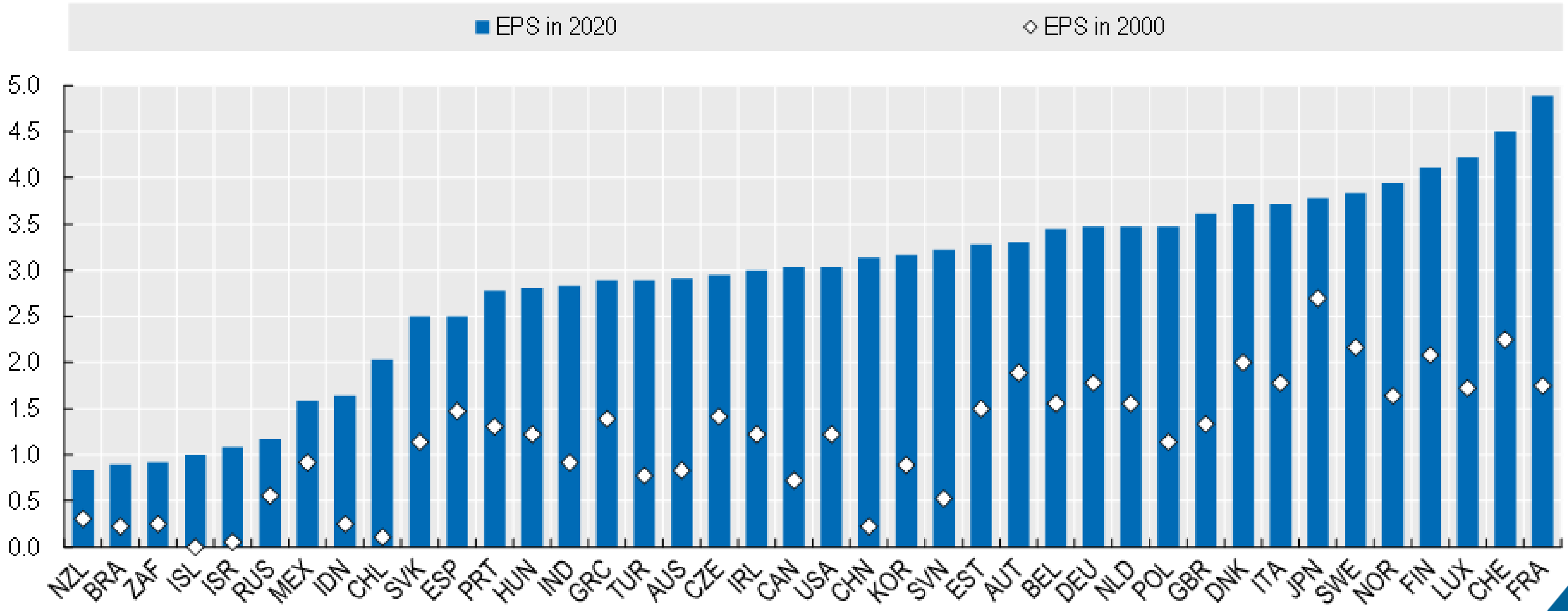
Climate policy stringency in OECD countries, 1990-2020



Source: OECD Environmental Policy Stringency indicator (2022)

...with large divergence across countries

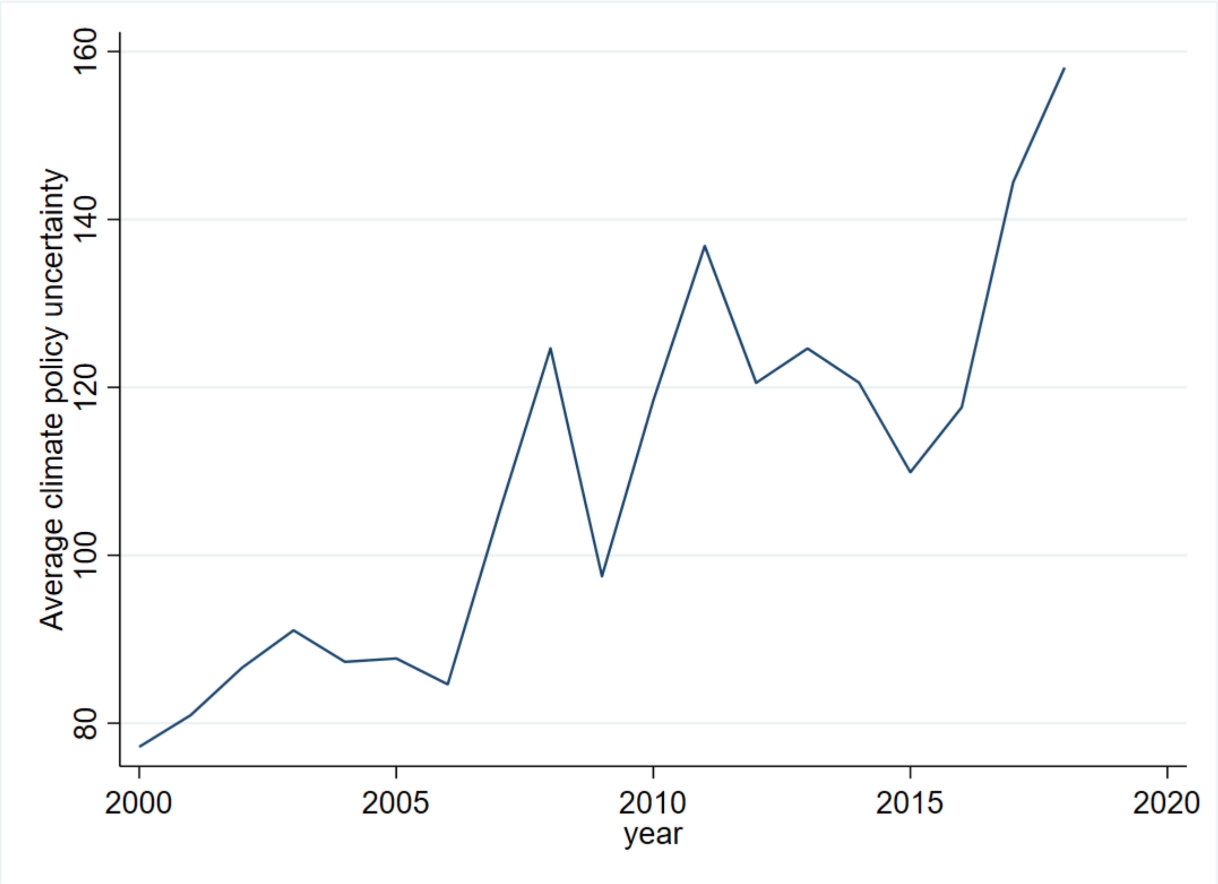
Climate policy stringency 2020 and 2000, by country

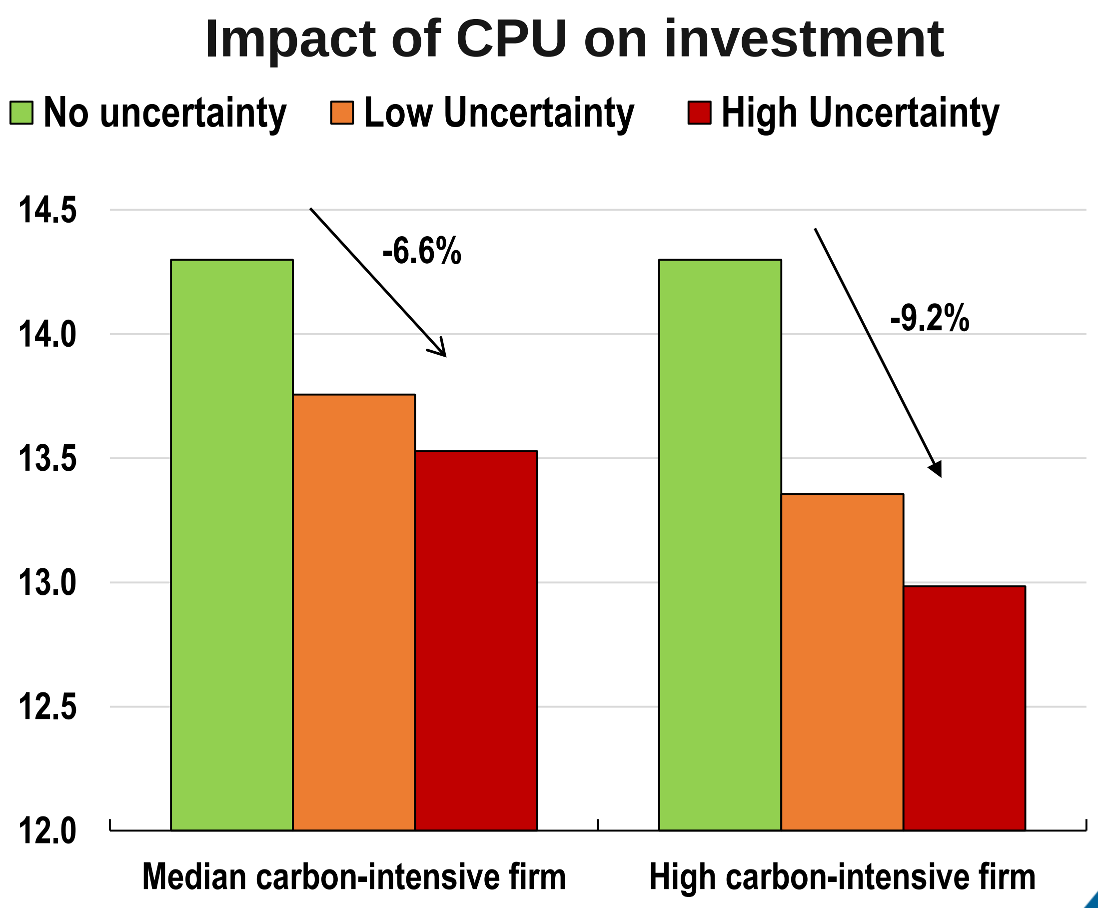


Source: OECD Environmental Policy Stringency indicator (2022)

Increasing climate policy uncertainty

Climate policy uncertainty average
(12 countries), 1990-2020

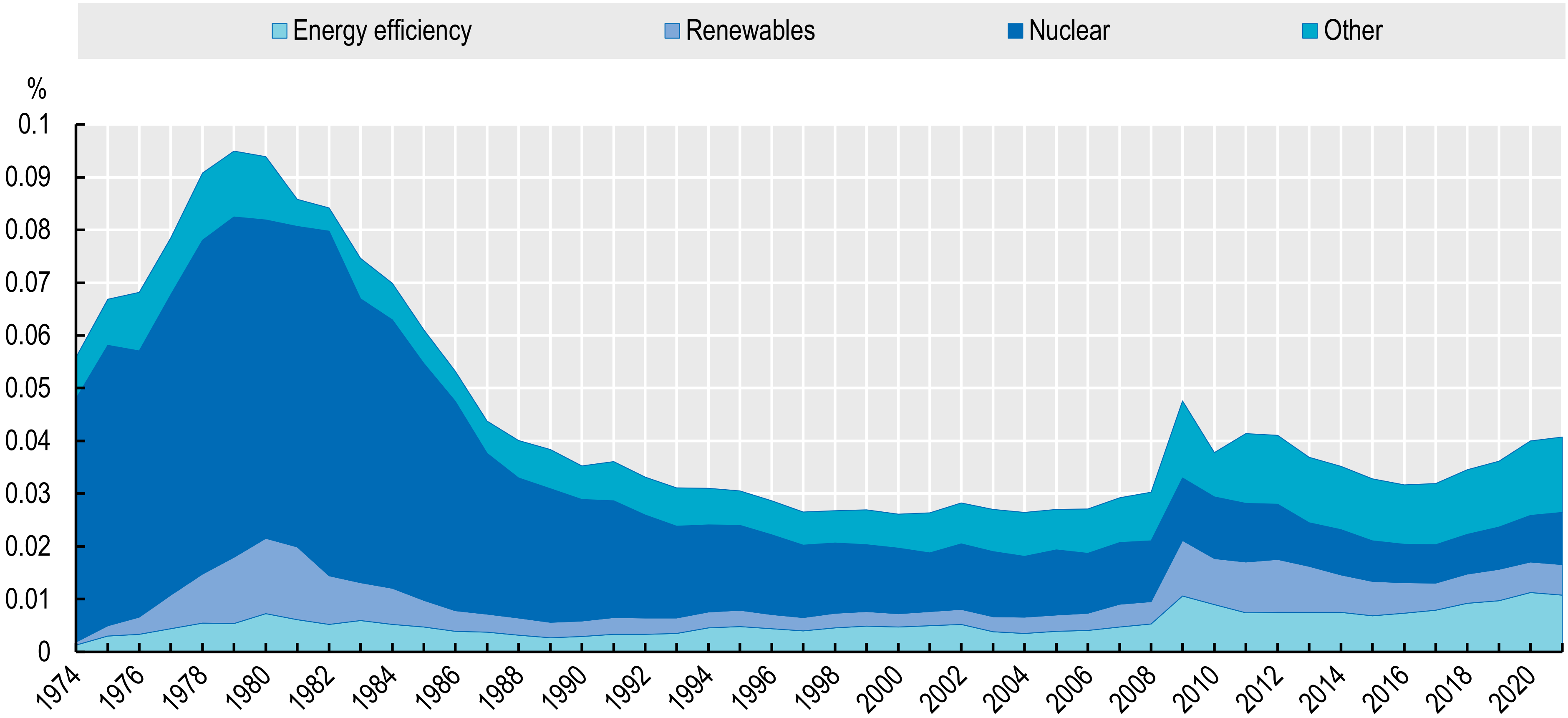




Source: Berestycki, C. et al. (2022), "Measuring and assessing the effects of climate policy uncertainty", OECD Economics Department Working Papers, No. 1724

Insufficient public support for R&D …

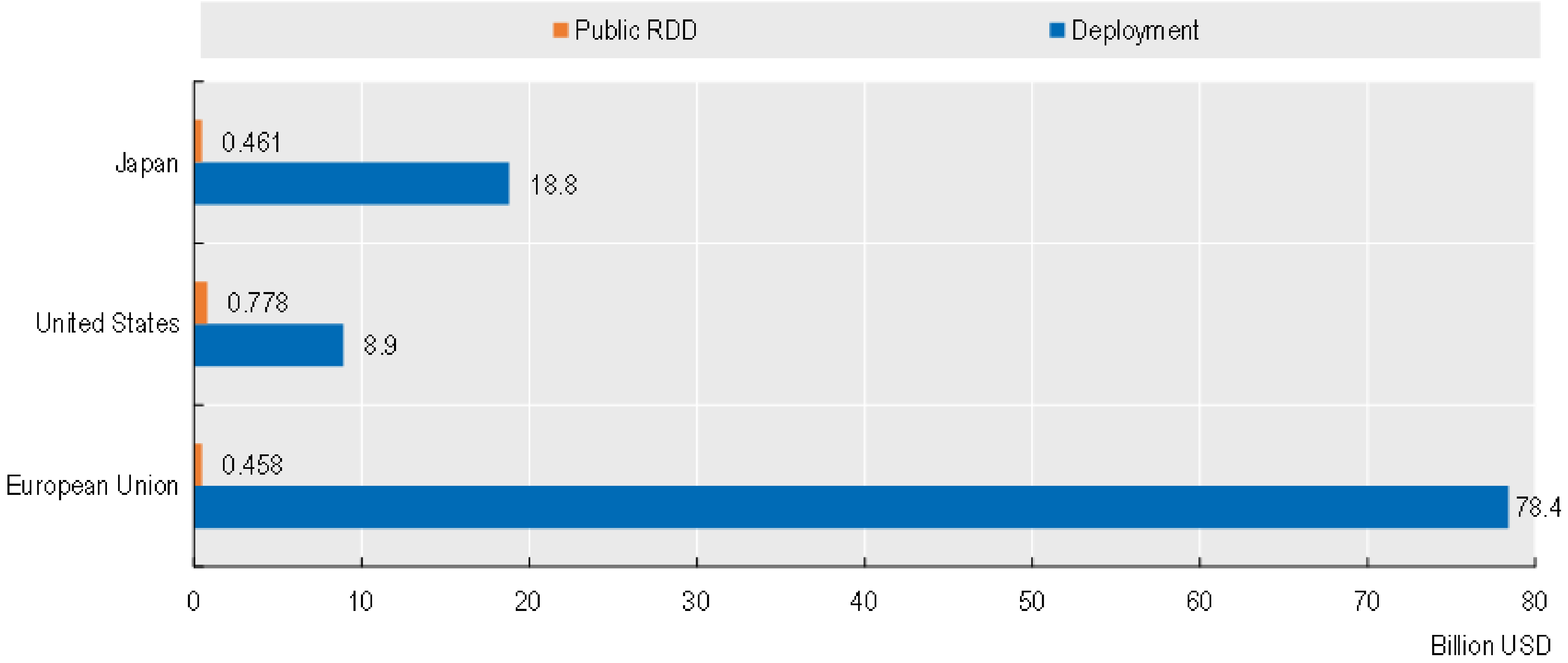
Low-carbon public R&D expenditures in GDP, 1974-2021



Source: IEA Energy RD&D public expenditures (2023)

...compared to large support for deployment (e.g. renewables)

Public RD&D vs deployment support in renewable energy 2018 (bn USD)

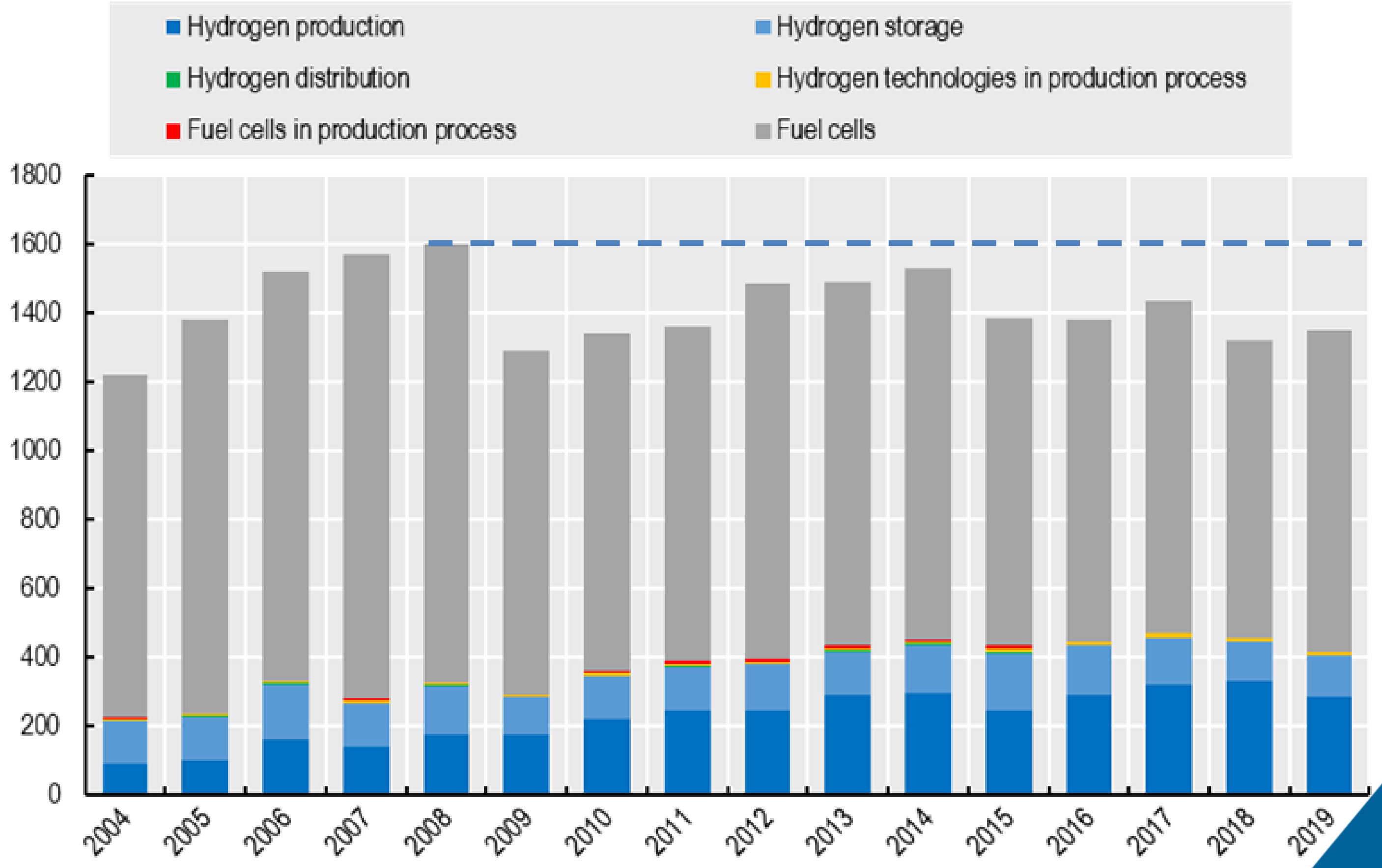


Source: IEA (RD&D); IRENA (deployment)

Example hydrogen: stagnating global innovation efforts (patents)…

- Number of patents smaller since 2009 than in 2008
- Rise in hydrogen production patents, decrease in fuel cells
- The pace of innovation activity is not aligned with new hydrogen ambitions

Number of annual patent filings in different hydrogen technologies, 2004-19



Source: OECD, STI Micro-data Lab

… compared to ambitious planned deployment through massive public subsidies

- Planned capacity deployment = 175 GW green capacity; 40 Mt H2/year
  - Net-zero scenario needs: 3 600 GW electrolysis and 500 Mt H2 by 2050
- Cost of deployment likely very high unless innovation brings this down

Planned hydrogen capacity in main economies

Country	GW (green)	Mt H2/year (green+blue)
Spain	35.2	6.1
France	34.4	6.0
United Kingdom	1.8	4.9
Australia	25.7	4.6
Netherlands	10.3	4.1
Germany	12.1	2.4
Canada	0.1	1.8
China	8.0	1.4
United States	1.5	0.7
Italy	1.1	0.2
Japan	0.01	0.003
TOTAL world	175	40.3

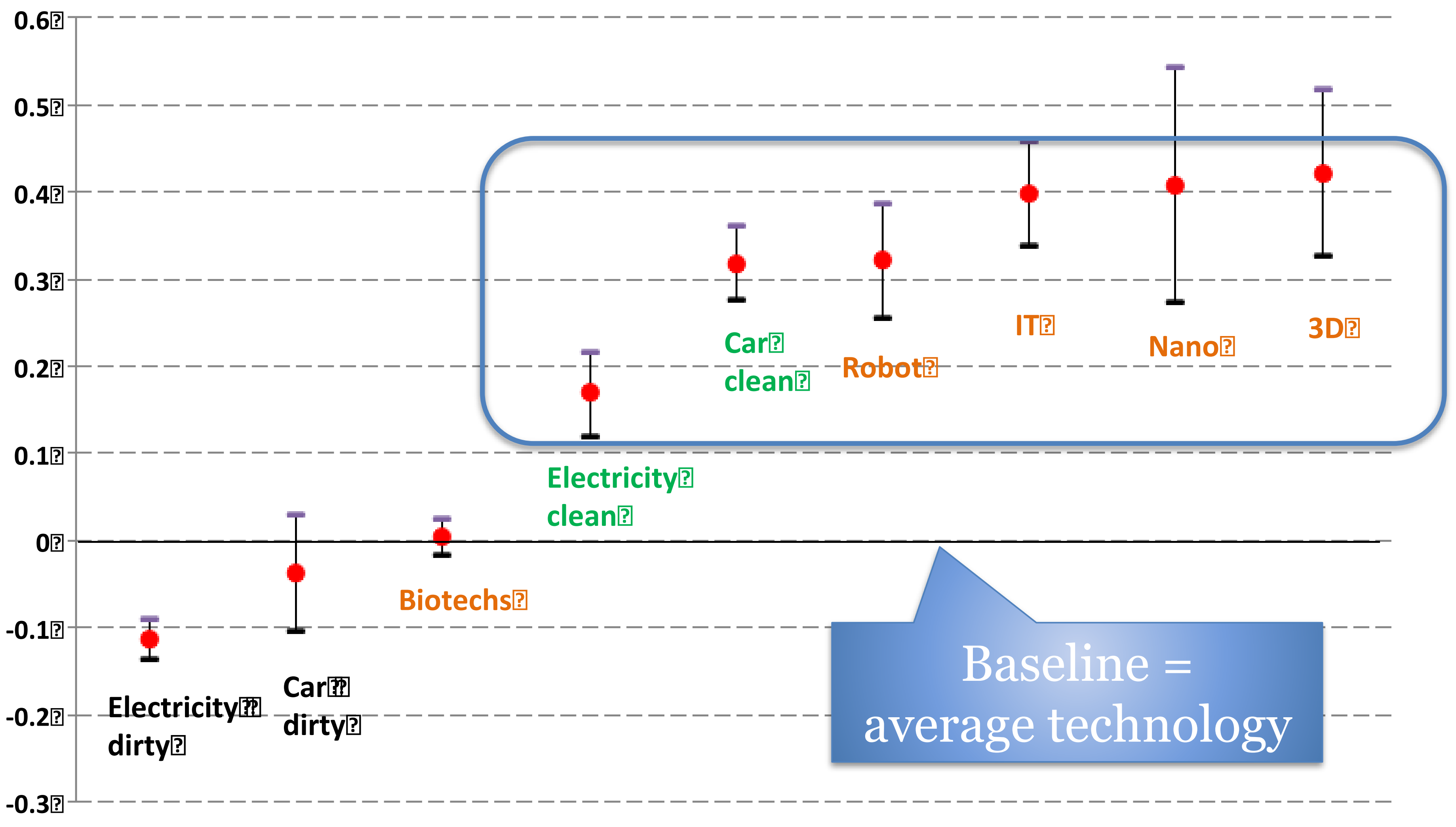
Source: own calculations based on IEA (2021).

THE CASE FOR LOW-CARBON INNOVATION POLICIES

Multiple barriers impede low-carbon innovation

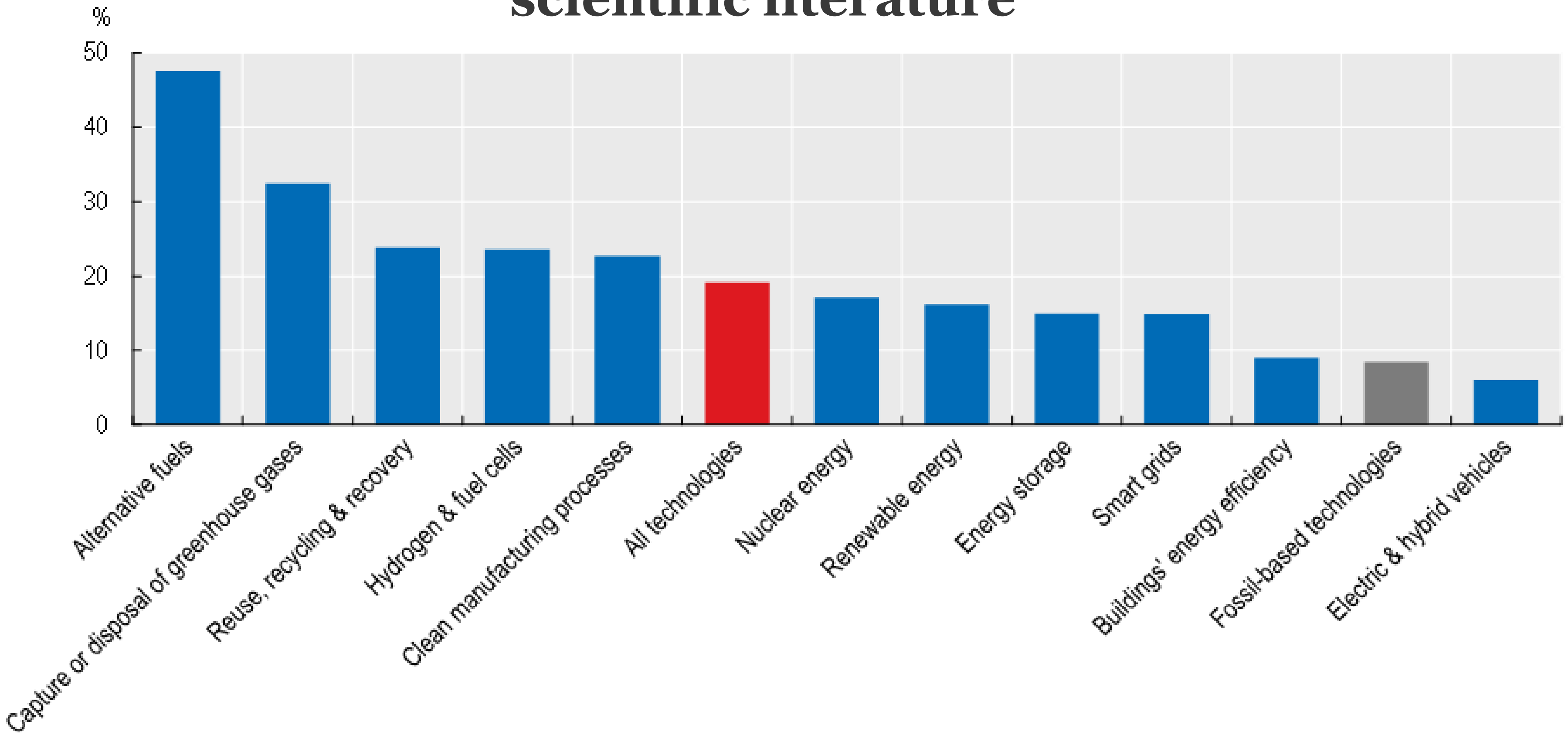
- Market failures: environmental externalities, knowledge spillovers, information asymmetries
- Inertia and systemic barriers, including path-dependence & limitations to competition
- Lack of capabilities
- Government failures eg policy uncertainty

Large knowledge spillovers in clean tech (as in other emerging fields)



Low-carbon innovations rely on scientific research more than fossil-based innovations

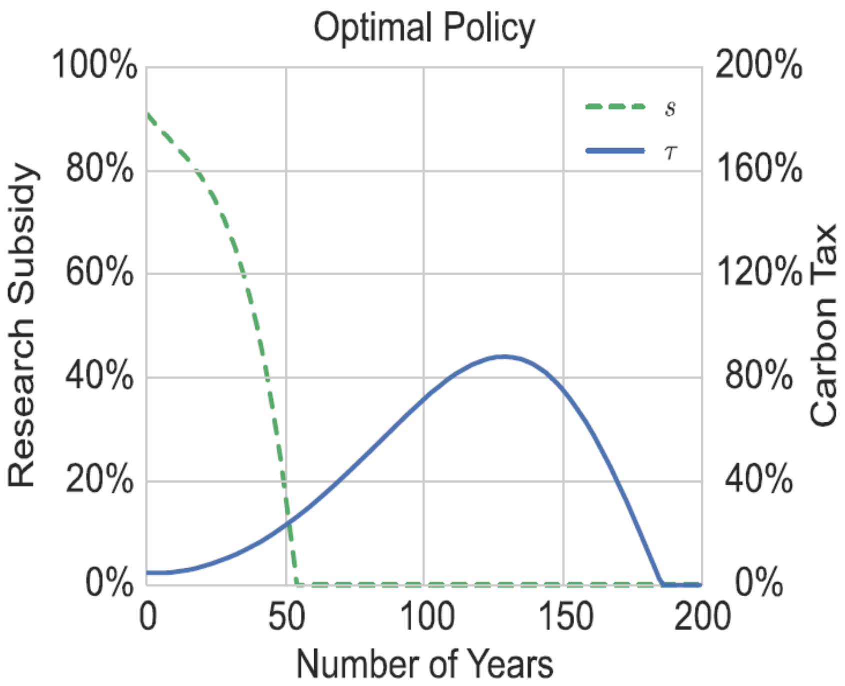
Share of patents applications in low-carbon technologies that cite scientific literature

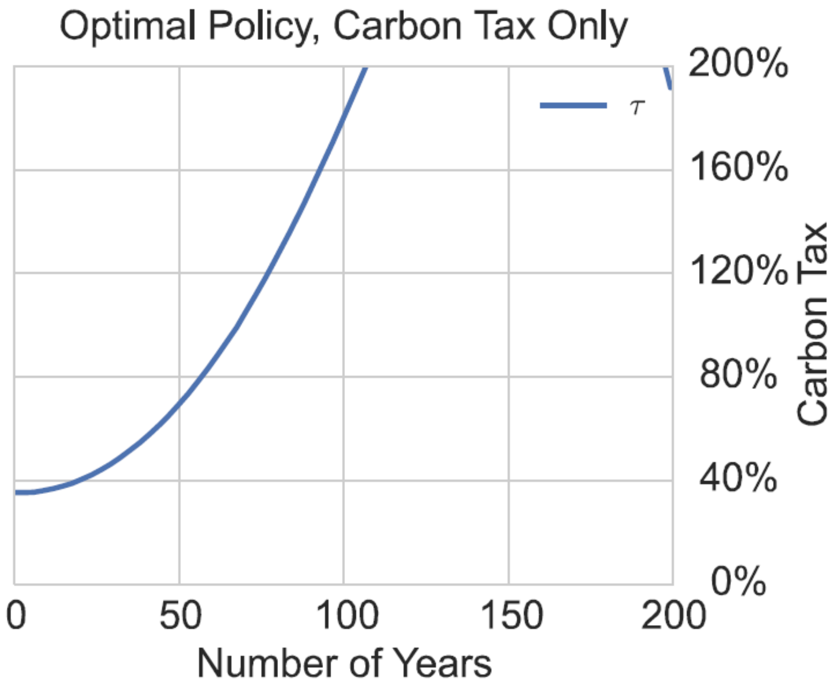


Source: OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, October 2022

Innovation policies reduce the cost of reaching climate objectives

Subsidies to clean research allow for much smaller carbon taxes





Source: Acemoglu et al., 2016. Transition to clean technology. Journal of Political Economy

STI policies are widely socially accepted, making them politically attractive

- Support to various climate policies (results from global OECD survey, 2000 respondents per country):

	High-income	Australia	Canada	Denmark	France	Germany	Italy	Japan	Poland	South Korea	Spain	United Kingdom	United States	Middle-income	Brazil	China	India	Indonesia	Mexico	South Africa	Turkey	Ukraine
Support for Main Climate Policies																						
Green infrastructure program	57	49	56	53	57	42	78	48	58	68	71	54	50	78	77	82	80	80	84	73	76	69
Ban on combustion-engine cars	43	35	47	41	28	32	54	41	44	52	54	45	39	65	60	72	77	65	67	53	62	58
Carbon tax with cash transfers	37	34	41	30	29	28	47	35	36	53	44	34	33	59	47	80	71	67	55	52	55	39
Support for Other Climate Policies																						
Subsidies to low-carbon technologies	67	62	65	67	56	64	79	69	75	71	73	65	57	73	77	75	68	79	66	75	75	68
Mandatory and subsidized insulation of buildings	66	70	64	70	64	60	73	59	72	72	71	70	53	75		80				73	75	75
Ban on polluting cars in city centers	60	53	60	66	57	50	76	64	61	52	64	65	49	71	65	73	74	85	72	66	60	67
Funding clean energy in low-income countries	54	49	50	53	48	48	76	53	55	57	65	51	50	73	63	71	75	81	74	76	66	78
Ban on combustion-engine cars w. alternatives available	48	38	47	42	42	41	58	51	48	58	57	52	44	68	60	78	77	72	66	62	64	63
Tax on flying (+20%)	45	35	44	60	46	53	41	47	44	42	44	46	33	52	39	61	64	68	51	43	45	36
Tax on fossil fuels ($45/tCO2)	36	36	40	43	31	31	38	35	27	42	39	38	34	48	35	58	64	58	41	38	52	28
Support for Carbon Tax With:																						
Funding environmental infrastructures	63	60	48	60	65	60	76	56	68	78	69	63	56	75	78	76	71	81	73	79	73	69
Subsidies to low-carbon tech.	63	58	49	52	57	66	76	68	71	79	69	59	53	73	74	79	68	79	71	78	66	65
Reduction in personal income taxes	57	52	48	38	62	54	72	64	69	62	67	52	49	69	69	74	68	74	69	68	66	64
Cash transfers to the poorest households	53	51	48	41	55	47	68	54	50	59	63	57	46	73	67	82	69	86	66	65	82	62
Cash transfers to constrained households	50	50	42	36	55	47	62	47	39	62	61	52	44	64	59	69	63	74	59	60	65	61
Tax rebates for the most affected firms	48	41	41	38	52	34	66	49	61	59	55	41	43	62	59	72	65	68	54	63	55	56
Reduction in the public deficit	48	40	39	34	49	39	66	50	56	48	62	44	48	63	62	72	65	70	61	62	57	52
Equal cash transfers to all households	38	37	38	27	45	31	42	43	37	42	44	33	38	61	45	70	64	76	62	57	59	53
Reduction in corporate income taxes	37	29	32	24	37	25	55	38	48	48	50	26	29	58	54	67	60	67	61	50	60	42
Support for Cattle-Related Policies																						
Subsidies on organic and local vegetables	56	42	50	59	52	56	71	46	73	62	65	49	43	68	62	79		77	58	59	80	58
Ban of intensive cattle farming	42	32	41	31	55	49	64	17	44	44	43	50	36	39	38	50		45	46	28	32	25
Removal of subsidies for cattle farming	34	31	33	32	28	38	42	16	34	31	42	37	38	39	43	47		51	47	27	31	22
A high tax on cattle products, doubling beef prices	30	24	27	31	29	40	37	19	30	26	31	31	31	36	33	48		49	37	30	26	24

Source: Dechezleprêtre, A. et al. (2022), "Fighting climate change: International attitudes toward climate policies", OECD Economics Department Working Papers, No. 1714

WHAT CAN POLICIES DO?

Making STI policies a cornerstone of climate policies

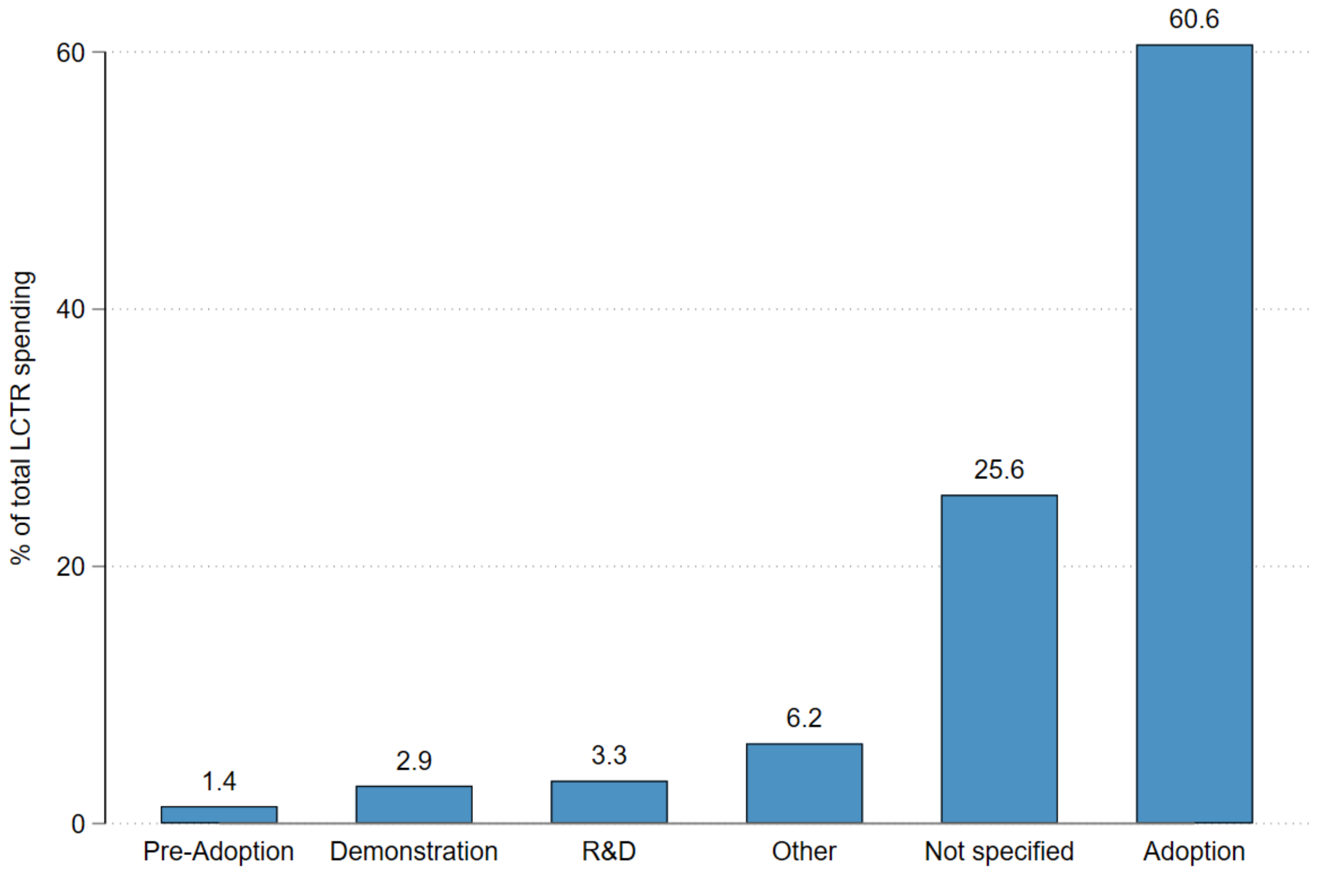
- Reducing costs to make carbon-free technologies competitive with their high-carbon alternatives should be a primary objective of climate policy
- Innovation and industrial policies should constitute a cornerstone of strategies to reach carbon neutrality
  - Theoretical justifications very strong
  - Can partially substitute for low carbon prices and support carbon pricing
  - Can facilitate the adoption of more ambitious climate policies
  - Can boost international technology diffusion to emerging economies

Encouraging innovation directly

- Re-balancing STI policies: greater **support for breakthrough technologies**, and better balance with **diffusion of existing technologies**
  - Target early-stage low-carbon technologies (e.g. H2), enabling technologies (e.g. digital) and focus deployment on infrastructure (e.g. charging stations)
  - Increase support for **demonstration projects** – currently too small compared to typical project needs (eg EU Innovation Fund vastly oversubscribed)
  - Growing and predictable **budgets**

Covid-19 recovery packages might help

- USD 1.3 trillion targeted at low-carbon technologies in covid recovery packages
- **7% to R&D and demonstration**, and strong push for some emerging technologies: **hydrogen**, **smart grids** and **CCUS**



Encouraging innovation directly

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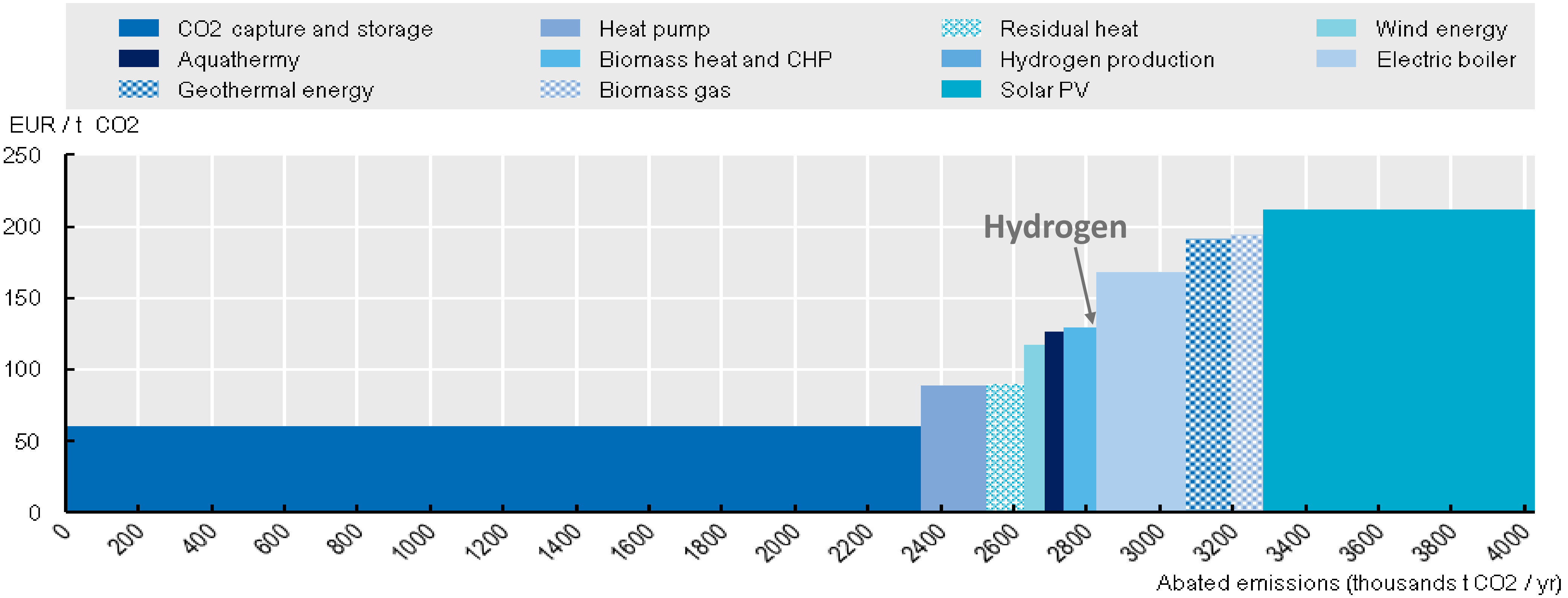
  - Target early-stage low-carbon technologies (e.g. H2), enabling technologies (e.g. digital) and focus deployment on infrastructure (e.g. charging stations)
  - Increase support for **demonstration projects** – currently too small compared to typical project needs
  - Growing and predictable **budgets**
- More **direct** support instruments, not just R&D tax credits – technology neutrality is not neutral, but tends to favours incumbents
  - Direct support works (eg Howell 2017) but more research needed

Technology-neutral policies favour mature technologies

SDE++ subsidy demand curve in first tender (Netherlands)



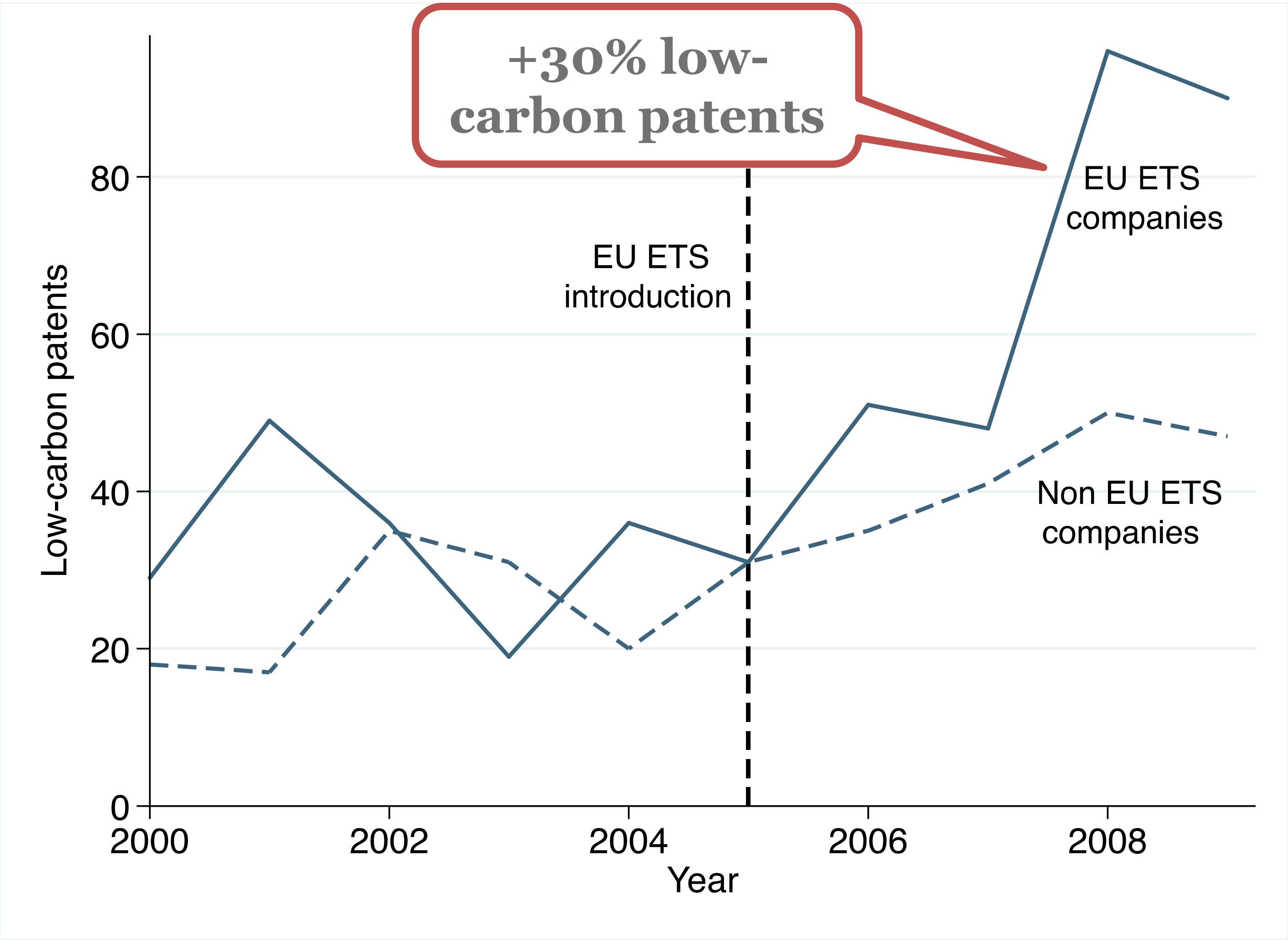
Note: average requested subsidy per ton CO2 at the technology category level inferred from the requested total amount and the eligible energy production, using PBL's emission factors to transform the eligible energy production in avoided emissions.

Source: OECD calculations based on RVO and PBL data (Anderson et al., 2021[15]).

Provide clear indication on direction of change

- Carbon pricing (to ensure tax-inclusive fossil prices won't go back down) and removal of fossil fuel subsidies

Pricing carbon encourages low-carbon innovation



Source: Calel & Dechezleprêtre, 2016. "Environmental Policy and Directed Technological Change: Evidence from the European carbon market". *Review of Economics and Statistics*

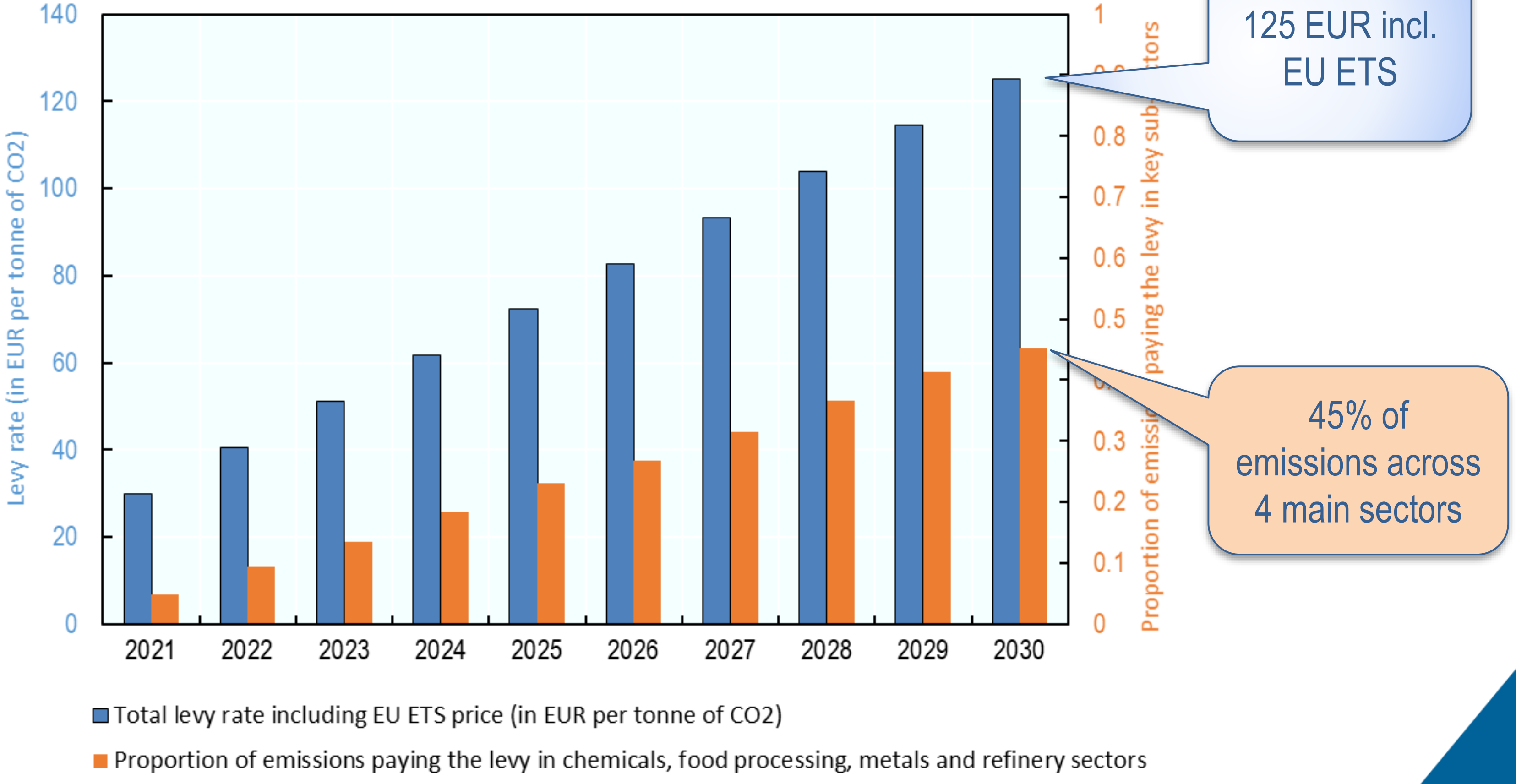
Provide clear indication on direction of change

- Carbon pricing (to ensure fossil prices won’t go back down) and removal of fossil fuel subsidies
- Reduce policy uncertainty

The Dutch climate levy: a gradual yet strong signal to incentivize decarbonisation

- A strong medium-term signal
- Provides certainty
- Kicks-in gradually

Levy rate 2021-2030 and estimated proportion of emissions covered



Note: The levy rate includes the floating national contribution and the EU ETS price. The estimated proportion of emissions paying the levy covers only the chemicals, food processing, metals and refinery sectors.

Provide clear indication on direction of change

- Carbon pricing (to ensure fossil prices won’t go back down) and removal of fossil fuel subsidies
- Reduce policy uncertainty
- Stir **demand** for low-carbon technologies
  - Product **standardisation** (e.g. green hydrogen, sockets for EVs, etc.)
  - **Regulation** (e.g. heating, buildings, emissions standards, recycled content, bio-based products)
  - Public procurement

Providing the right framework conditions

- Fund **public infrastructure,** e.g. EV charging stations, carbon and hydrogen pipelines, 5G.
- **Support entrepreneurship,** address **incumbency and rent-seeking**
- Preserve **competition**, contestability of markets and openness
- **Make trade work for the twin transition** – e.g. facilitating trade in environmental goods and services, IPR frameworks that balance protection and diffusion, etc. …
- **Support workers**, whose skills need to be updated

For more information:

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APPENDIX:
Future research on climate policy and innovation

Measurement issues

- Measuring clean innovation
  - Patents = the tip of the iceberg. 4% of UK *innovating* firms patent (Hall 2013)
  - Other measures of innovation much needed: new products (eg Newell et al 1999), technology cost reductions
- Measuring environmental policy stringency
  - *Expected* future policy stringency (Martin, Muûls, De Preux, Wagner 2012). NLD carbon levy
  - Effect of policy uncertainty

What is the effect of policies on innovation beyond directly treated firms?

- Impact higher up the supply chain (technology providers)
- Impacts downstream through cost pass-through
- Cross-border impacts (countries/state)
- Knowledge spillovers
- Product market rivalry

➢ SUTVA violations

➢ Trade-off between establishing causality and determining the total impact of policies

What is the impact of climate policies on non-clean innovation?

- Impact on innovation in dirty technologies
  - Clean & dirty technologies might be complementary (eg hybrid cars)
  - Dirty techs also respond (clean coal, fuel efficiency, shale gas, oil sands…)
- Impact on innovation that improves clean/dirty substitutability (eg energy storage, smart grids)
- Which technologies are crowded out by inducing more clean innovation?
  - Productivity-improving innovation? (Popp and Newell 2012)
  - Inventors switching to clean

Is explicit emissions pricing always the best option?

- Theory clear, but:
  - Some empirical evidence that replacing command-and-control regulation with permit trading *decreased* innovation (Popp 2003, Taylor 2012)
  - Predictability vs flexibility
  - Prices ineffective in some sectors (eg buildings)
  - Political acceptability (eg US IRA)
- Which policies for which sectors/techs?
  - Depending on maturity (breakthrough vs mature technologies)

What instruments beyond pollution pricing?

- Other market failures justify additional instruments
  - Knowledge spillovers, learning by doing, second-mover advantage
  - What is the size of these market failures? (Dechezleprêtre, Martin & Mohnen 2017) Do we need specific policies for clean techs?
- Do clean R&D subsidies work?
  - Large general literature, but little on energy innovation (Pless, Hepburn & Farrell 2020; Howell 2017 exception)
  - Energy innovation specific: capital intensity, long time horizons, little product differentiation
- Complementary instruments – which combinations of instruments work best?
  - Analyse interactions of instruments
  - Optimal policy mix (eg demand side vs R&D)

Impact of clean innovation on environmental policy stringency

- Reverse causality: innovation can make it easier to implement stricter policies
  - Ex: Carrion-Flores & Innes (2010): bidirectional link
  - Dugoua (2020): innovation induced by Montreal protocol reduced future abatement costs, leading to a series of increasingly ambitious follow-up agreements
- Very important policy implications on best sequencing of climate policy instruments
  - Innovation/adoption support first; then carbon pricing?
  - Carbon pricing and technology development self-reinforcing