The Transition in the economics of climate change and Energy Transition

Or, "How to [em]power > 10 billion people (without wrecking our climate)?

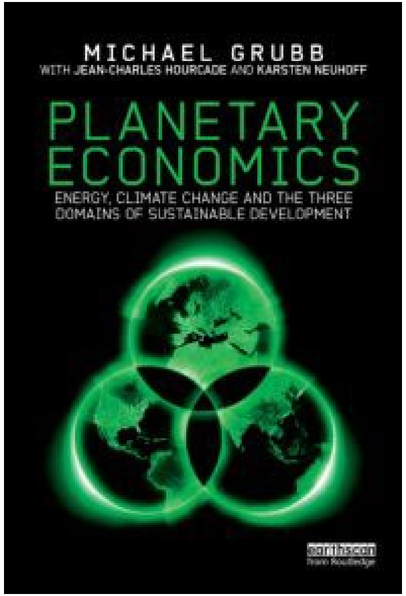
Presentation to World Bank ABCDE Conference, Washington, 5th June 2023

Michael Grubb, Professor of Energy and Climate Change, UCL

Convening Lead Author, IPCC Sixth Assessment Report – Mitigation

Former Chief Economist, the UK Carbon Trust and initial member, UK CCC

Chair, UK Panel of Technical Experts on Electricity Market Reform



Energy, Climate Change and the Three Domains of Sustainable Development

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Sixth Assessment Report
WORKING GROUP III – MITIGATION OF CLIMATE CHANGE

INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Climate Change 2022

Mitigation of Climate Change

Report by numbers

278 Authors

65 Countries

41 % Developing countries
59 % Developed countries

354 Contributing authors

29 % Women / 71 % Men

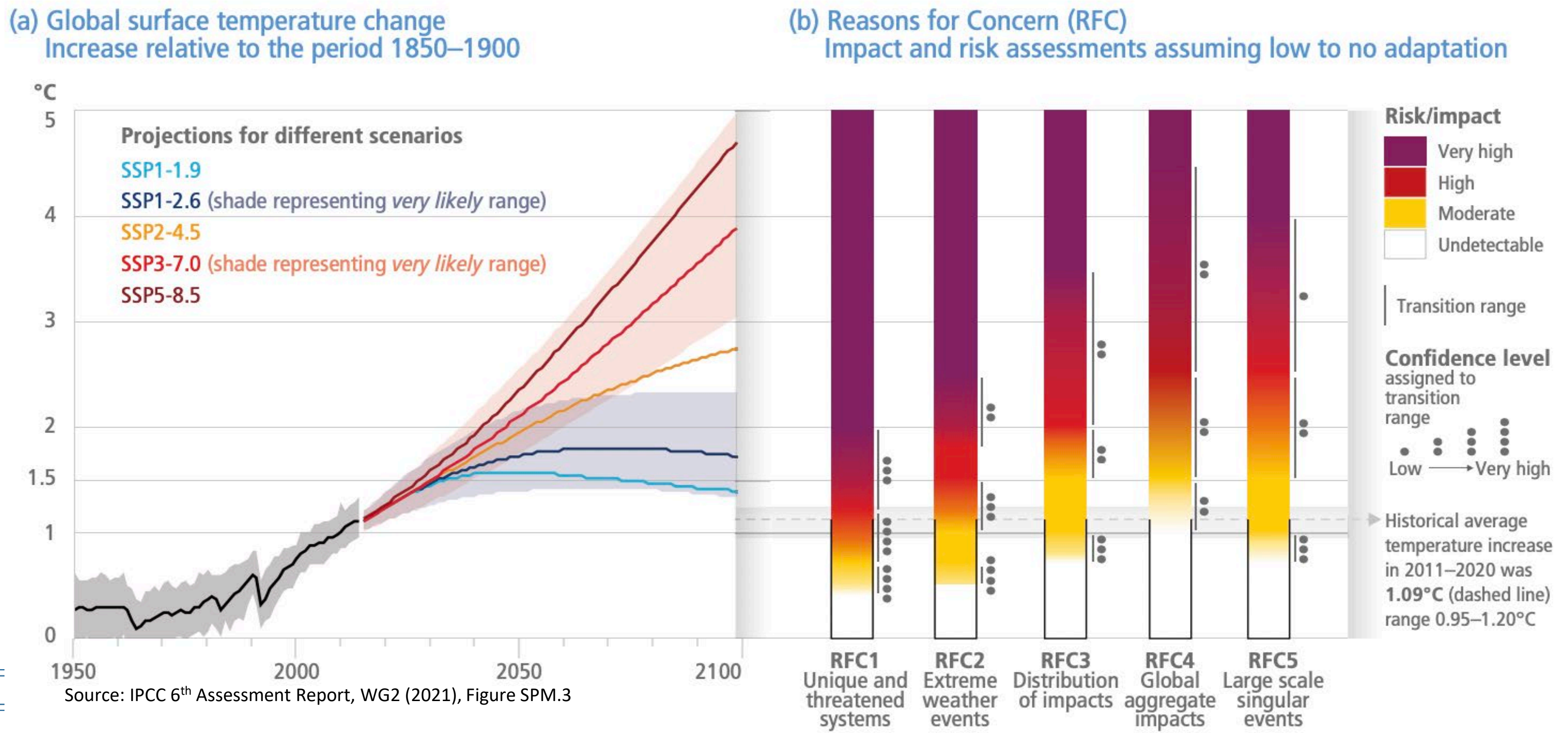
More than 18,000 scientific papers

59,212 Review comments

Different emission trajectories => *very* different temps by 2100

IPCC 6th Assessment Report (WG1, Science) – 5 wide scenarios to 2100

[SSP Numbers refer to radiative forcing levels (W/m^2) associated with GHG concentrations]



Source: IPCC 6th Assessment Report, WG2 (2021), Figure SPM.3

Series of studies imply a substantially higher 'SCC'

'Social Cost of Carbon' emissions – economists' instinctive indicator ..

IPCC Sixth Assessment (2022): Relative to IPCC AR5 Report (2014), **more estimates, greater variation,** and "**more recent estimates significantly higher** than the range reported in AR5"

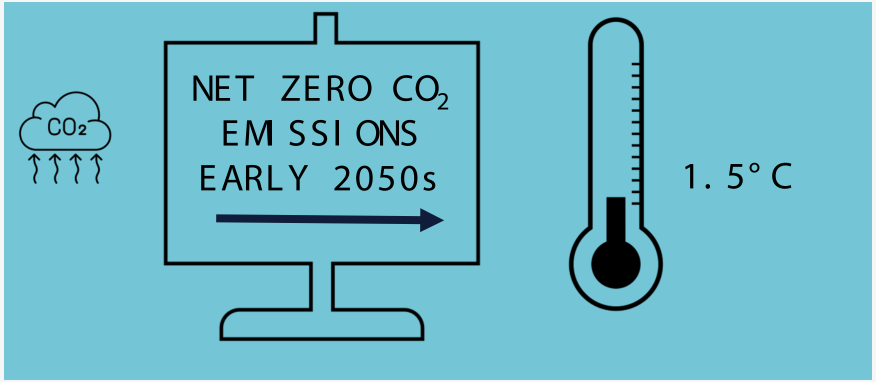
Rennert et al. (2022) 'Comprehensive evidence implies a higher social cost of CO2', Nature Journal

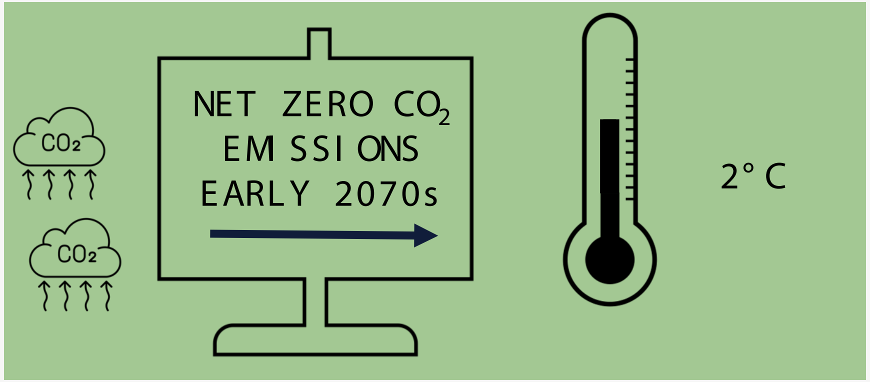
- **Responds to** 2017 report by the **US National Academies of Sciences, Engineering, and Medicine1 (NASEM)** highlighted that current SC-CO2 estimates no longer reflect the latest research …
- Incorporated novel components for each step of the SCC calculation, improving probabilistic socioeconomic projections, climate models, damage functions, and discounting methods, incorporating recent advances not accounted by the previous generation of studies
- **Preferred mean SC-CO2 estimate is $185 per tonne of CO2** ($44–$413 per tCO2: 5%–95% range, 2020 US dollars) at a near-term risk-free discount rate of 2%, a value **3.6 times higher than the US government's current value of $51 per tCO2.**

'The social cost of carbon has increased over time' – Richard Tol, *Nature Climate Change, 15 May 2023*

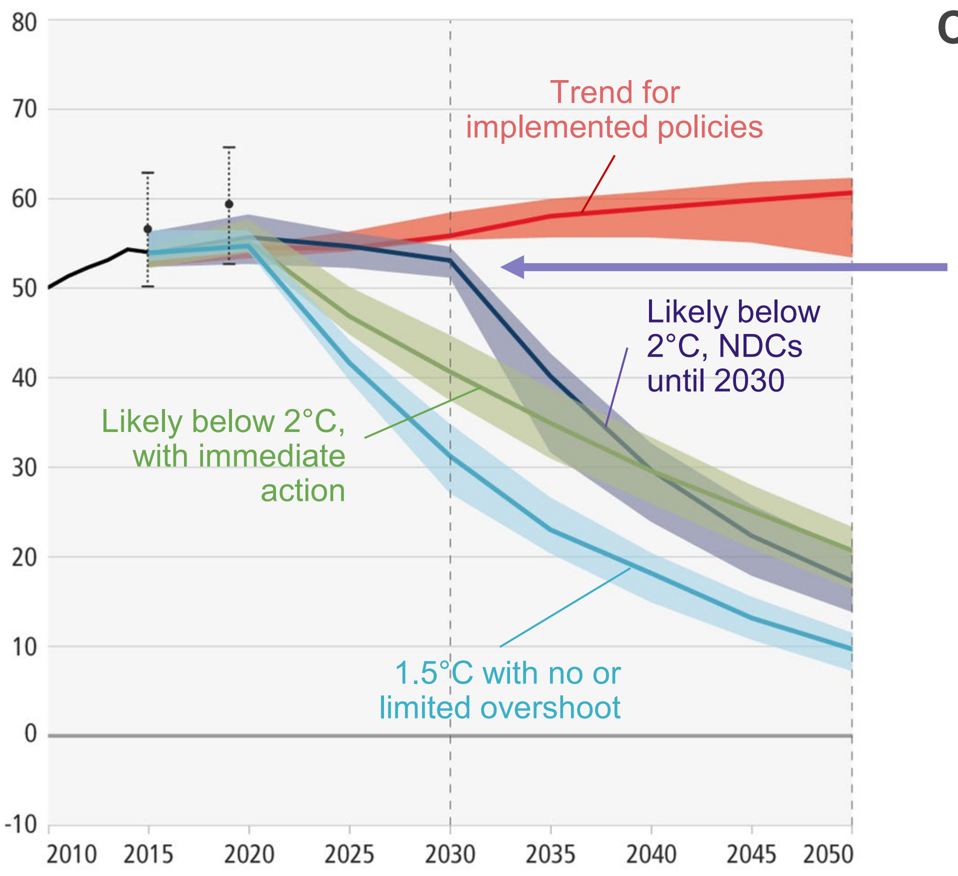
=> If fully costed, **climate damage per unit exceeds price of coal, and > $50/bbl oil**

The longer term: temperature will stabilise when we reach global net zero carbon dioxide emissions





(based on IPCC-assessed scenarios, indicating prompt and deep emission reduction scenarios to be the most cost-effective path towards the Paris temperature range)



Current trends and 2030 targets ..

- Barely stabilise *emissions*, concentration & temp keep rising
- Paris Agreement 'Nationally Determined Contributions'

Limiting warming to 1.5 °C

- Global GHG emissions peak before 2025, reduced by 43% by 2030.
- Methane reduced by 34% by 2030

Limiting warming to around 2°C

- Global GHG emissions peak before 2025, reduced by 27% by 2030.

(based on IPCC-assessed scenarios)

Analytic approaches – a broad landscape

Some characterisations

"The biggest market failure in history"
(Nicolas Stern, 2005)

"The perfect moral storm"
(Steve Gardiner, 2011)

A "Super-Wicked" problem
(Lazarus, 2009; Kelly Levin et al, 2012)

"'Psychological distance' - our brains are hard wired to ignore climate change"
(Marshall, 2014; also Weber 2018, 2020; Spence et al 2012)

Four Analytic Frameworks

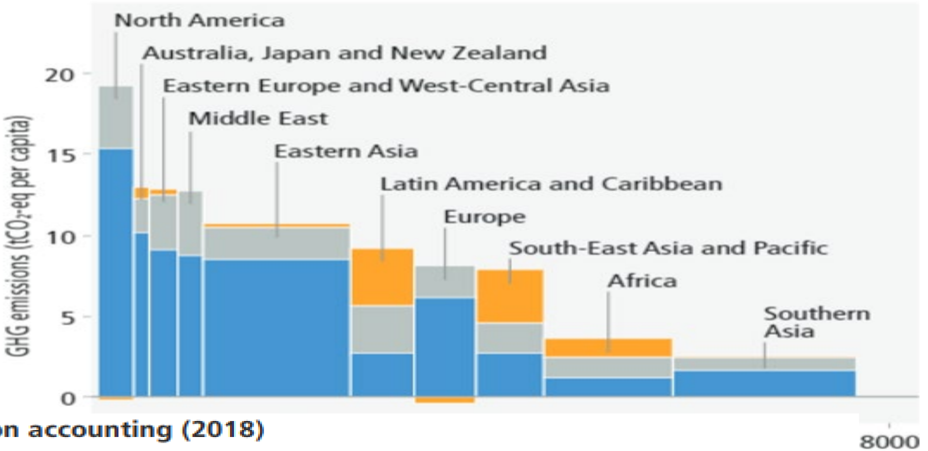
- Aggregate Efficiency
- Ethics and Equity
- Innovation & transition dynamics
- Psychology and politics

Cited and outlined in IPCC Mitigation Report Chapter 1 Section 7, "Four Analytic Frameworks …

Regional and national per capita emissions partly reflect different development stages, also vary widely at similar incomes

- variations are large within the 'developed' countries, and within rest-of-world
- Emissions in Latin / Central America, SE Asia and Africa still dominated by non-fossil fuel GHGs
- Consumption-based ('footprint') accounting underlines inequalities and role of high consumption
- 10% of households with highest per capita emissions contribute 34-45% of global household GHGs

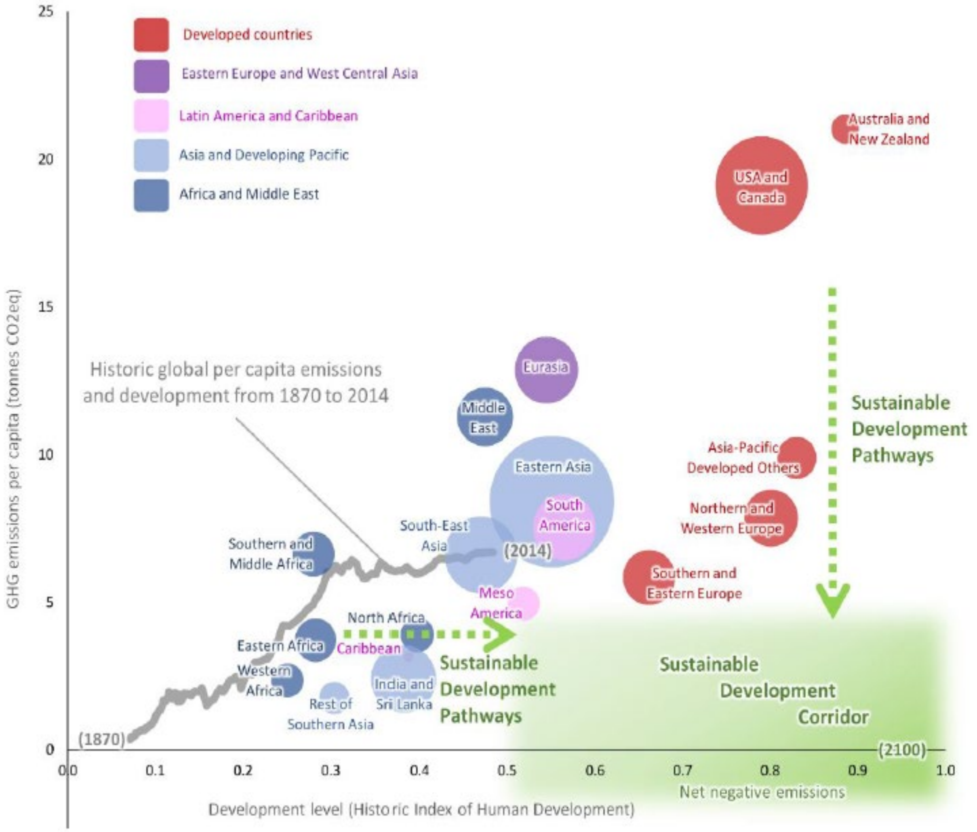
c. Net anthropogenic GHG emissions per capita and for total population, per region (2019)



d. Regional indicators (2019) and regional production vs consumption accounting (2018)

	Africa	Australia, Japan, New Zealand	Eastern Asia	Eastern Europe, West-Central Asia	Europe	Latin America and Caribbean	Middle East	North America	South-East Asia and Pacific	Southern Asia
Population (million persons, 2019)	1292	157	1471	291	620	646	252	366	674	1836
GDP per capita ($USD1000_{ppp}2017$ per person)[1]	5.0	43	17	20	43	15	20	61	12	6.2
Net GHG 2019[2] (production basis)										
% GHG contributions	9%	3%	27%	6%	8%	10%	5%	12%	9%	8%
GHG emissions intensity (tCO_2-eq / $USD1000_{ppp}$ 2017)	0.78	0.30	0.62	0.64	0.18	0.61	0.64	0.31	0.65	0.42
GHG per capita (tCO_2-eq per person)	3.9	13	11	13	7.8	9.2	13	19	7.9	2.6
CO_2-FFI, 2018, per person										
Production-based emissions (tCO_2-FFI per person, based on 2018 data)	1.2	10	8.4	9.2	6.5	2.8	8.7	16	2.6	1.6
Consumption-based emissions (tCO_2-FFI per person, based on 2018 data)	0.84	11	6.7	6.2	7.8	2.8	7.6	17	2.5	1.5

Close linkages between climate change mitigation, adaptation and development pathways.



gure TS.1: Sustainable development pathways towards fulfilling the Sustainable Development Goals

“.. development pathways .. at all stages of economic development impact GHG emissions and hence shape mitigation challenges and opportunities .. development choices and the establishment of enabling conditions for action and support, influence the feasibility and cost of limiting emissions {1, 3, 4, 5, 13, 15, 16}.

Climate change mitigation action designed and conducted in the context of sustainable development, equity, and poverty eradication, and rooted in the development aspirations of the societies within which they take place, will be more acceptable, durable and effective {1, 3, 4, 5}…”

[SPM, p.3]

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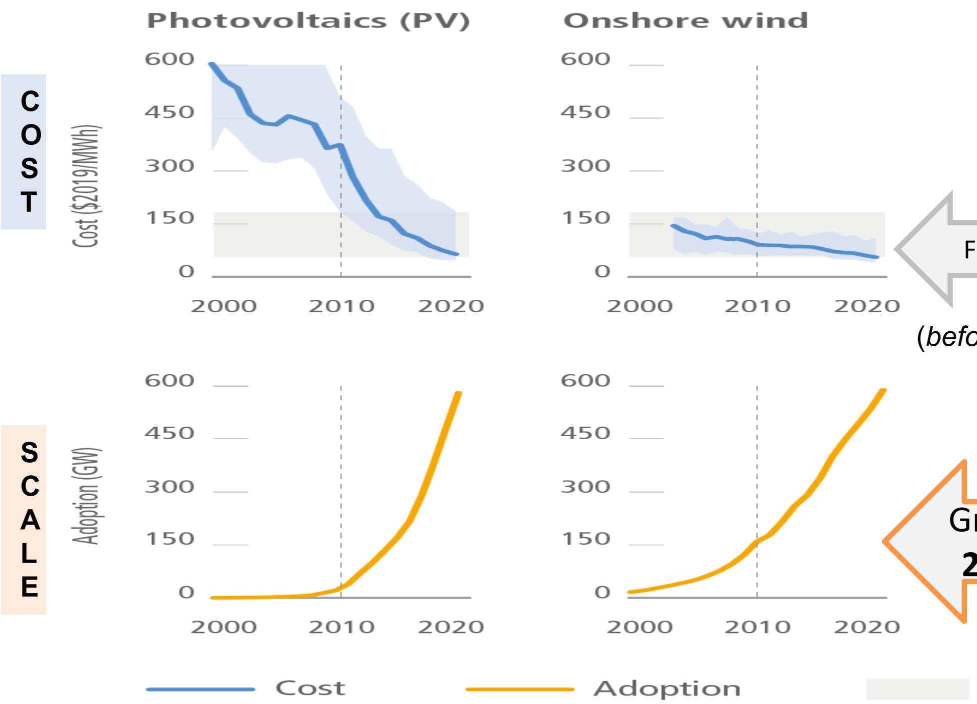
Astonishing progress in clean electricity techs

Solar PV is most dramatic – now at bottom of range of cost of new fossil fuel (like wind) … but not the only one ..

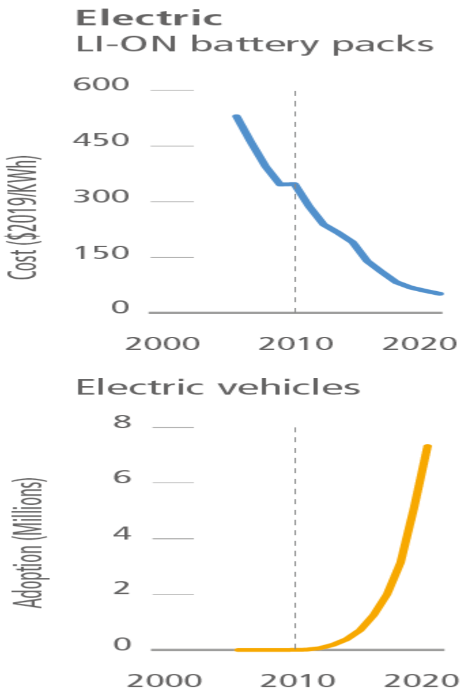
Batteries & Vehicles



FF Cost range

(*before* the crisis)

Growth rates
20-40+%.yr



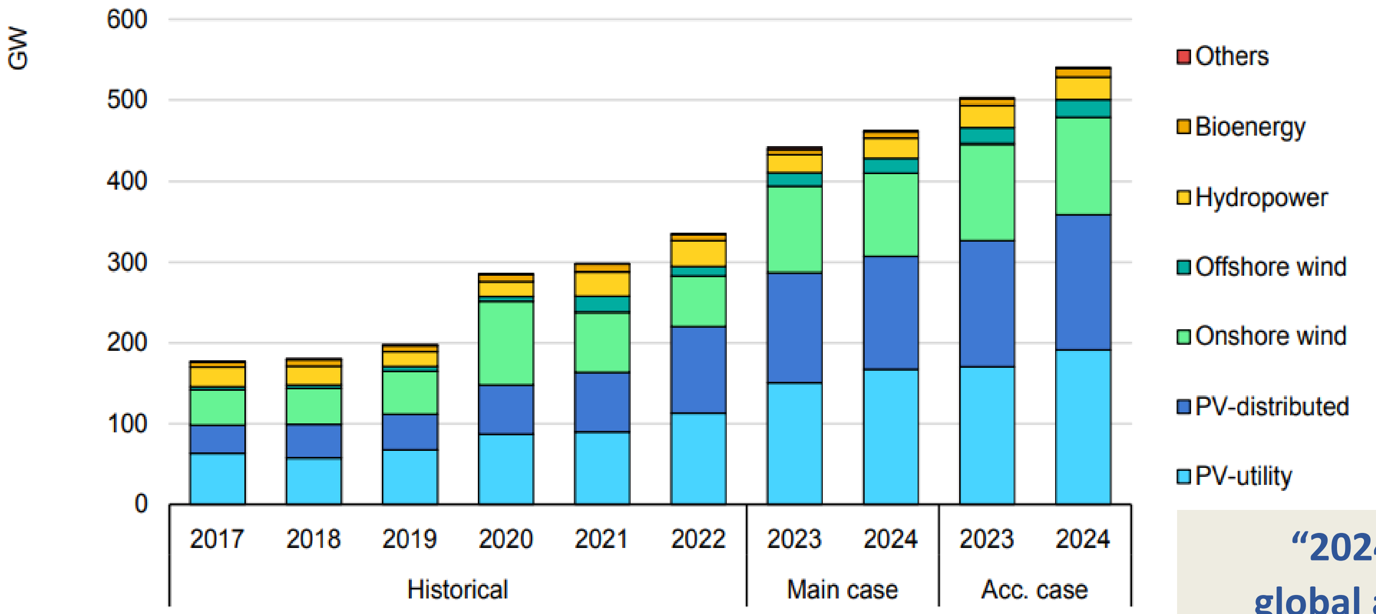
Clean electricity revolution is transforming elec *this decade*

Source: IPCC Sixth Assessment - Mitigation

The view from the International Energy Agency

"2023: Solar PV dominates growth, and onshore wind additional rebound to break the 2020 record"

Net renewable electricity capacity additions by technology, historical, main and accelerated cases



IEA, Renewable Energy Market Update, 1 June 2023

"2024: Another record year for global additions, led by solar PV"

Q: What two things do the following energy technologies have in common?

- Offshore oil extraction
- Shale gas
- Combined cycle gas turbines
- Solar PV
- Wind energy
- High efficiency lighting (LED lights)

[1] They all turned out to be ***much cheaper*** than anyone expected

[2] They all involved government action at scale over many years

- On both technology/resource development, and demand/price

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THE NEW ECONOMICS OF INNOVATION AND TRANSITION: EVALUATING OPPORTUNITIES AND RISKS

A REPORT BY THE ECONOMICS OF ENERGY INNOVATION AND SYSTEM TRANSITION (EEIST) CONSORTIUM

MICHAEL GRUBB, PAUL DRUMMOND, JEAN-FRANCOIS MERCURE, CAMERON HEPBURN, PETER BARBROOK-JOHNSON, JOÃO CARLOS FERRAZ, ALEX CLARK, LAURA DIAZ ANADON, DOYNE FARMER, BEN HINDER, MATT IVES, ALED JONES, GAO JUN, ULKA KELKAR, SERGEY KOLESNIKOV, AILEEN LAM, RITU MATHUR, ROBERTO PASQUALINO, CRISTINA PENASCO, HECTOR POLLITT, LUMA RAMOS, ANDREA ROVENTINI, PABLO SALAS, SIMON SHARPE, ZHU SONGLI, PIM VERCOULEN, KAMNA WAGHRAY, ZHANG XILIANG

Evidence: Learning from Successes

Wind: from 1 to 10-15% in Brazil and Europe in a decade

Policy support 'both push and pull' – R&D, collaboration, industry-building, public-backed banks and contracts

Cumulative improvements

Globalisation of the *market*

Financial involvement crucial

Big breakthroughs also in offshore wind costs

Solar PV: from 'the most expensive' to 'the cheapest electricity in history'

Long evolution from R&D through niche commercialisation

Breakthroughs from strategic commitment driving market scale

Internationalisation of *production*

Prompting Chinese domestic ambition and globalisation of diffusion

Energy efficient lights: from high-tech gadgets to lighting the poor

Indian energy-efficiency institutions stimulated by Kyoto's Clean Development Mechanism

Linked to drive for 'modern energy services'

Bulk public procurement and smart policy though electricity suppliers drove **85% cost reduction *in four years***

'The cheapest lighting in history'

These + forward looks at EVs and low carbon steel, now at eeist.ac.uk

Big themes from case studies

- Led by strong government action; all are now largely self-sustaining
- Would not have been pursued under traditional economic cost-benefit assessment – *nor were driven by the typical economists' policy prescriptions*
- Common themes include:
  - ***Cumulative progress.*** Built upon previous progress, not blue-skies lab breakthroughs (innovation is '*cumulative,* and *path-dependent')*
  - ***Market-based innovation*****.** market-based innovation and cost reduction, particularly associated with the deployment phase.
  - ***Sustained and targeted support beyond R&D*.** involved sustained support for deployment, mostly for 1-2 decades beyond the period dominated by public R&D.
  - ***Substantial uncertainties*****,** at least in the earlier stages of deployment until critical thresholds were passed.
  - ***Strong international dimensions.*** It was indeed internationalisation that often sustained the growth of the technologies and helped them pass critical thresholds.

The extreme caricatures are usually unhelpful

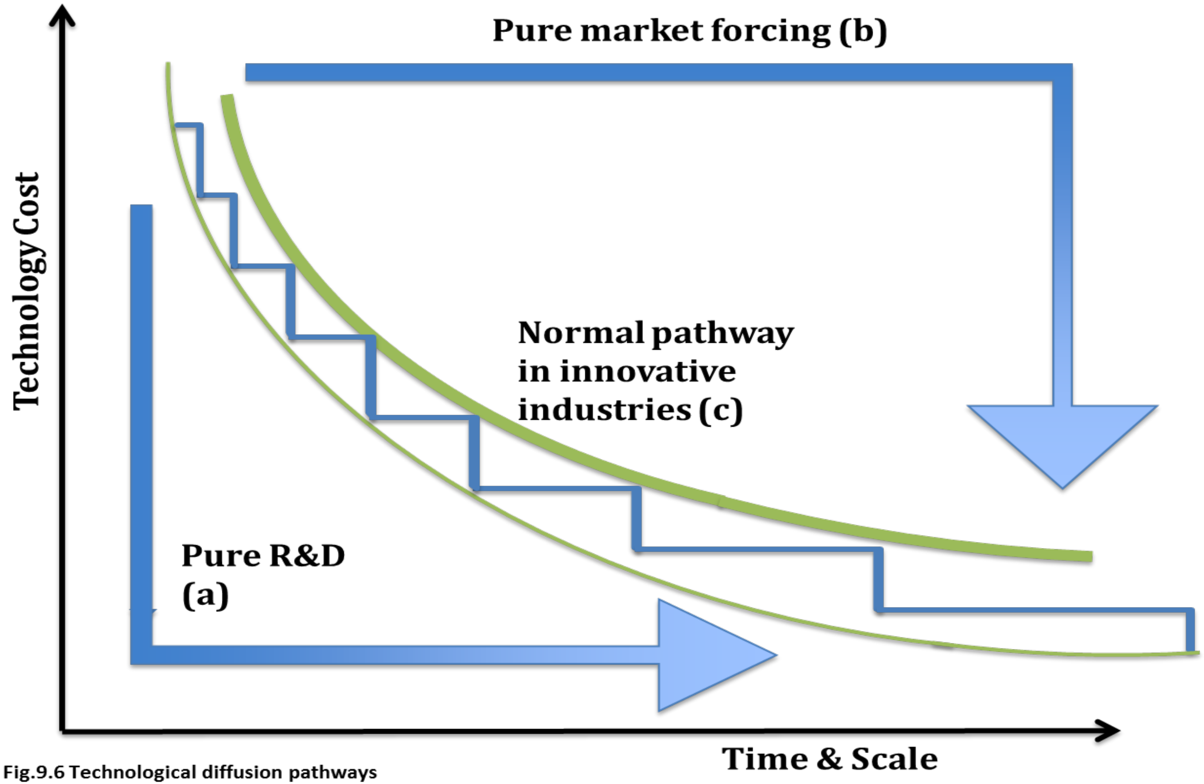


Fig.9.6 Technological diffusion pathways
Source: CIRED, France

… The reality is that most technologies have to evolve through repeated cycles of market growth, learning, scale economies and supply chain

Successful innovation must span complex 'multi-domain' journey

UCL

Technology journey	Basic R&D	Technology RD&D	Demonstration	Commerciali-zation	Market accumulation	Wide diffusion
Organisation & supply chain	1 or 2 individuals	Venture or new unit	First outsiders	Recruit specialists, Develop supply chain	Grow operational staff	Mature company or independent division
Customers and standards	No market defined	first targeting of possible markets	Choosing Market of commercial-ization	Early adopters and niches, basic standards	Expanding range of customers	Well defined customer Profile, trusted brand
Financing	Public or Internal funding	Internal funds or project grants	Internal funds, project grants, angel or VC investors	First sales, internal or external funds still needed	First profits	Financing through private equity, banks, etc.
Market Regulation	Neutral or negative regulation	Neutral or negative regulation	Neutral regulation	Specific positive regulation	Positive general regulation	Fully adapted regulatory environment
Institutional	Research institutions	Bespoke tech institutions	First sector associations	Eg. first IPO, licence acquisitions	Lobbying, corporate expansion	Stable role of associations in negotiating sector policy
Infrastructure	Research infrastructure	Test centres	Negative or neutral	'Piggybacking'/ First enabling infrastructure investments	Barriers from existing infrastructure	Adapted or dedicated infrastructure

1st

2nd

3rd

Growing social scale and role of higher domains

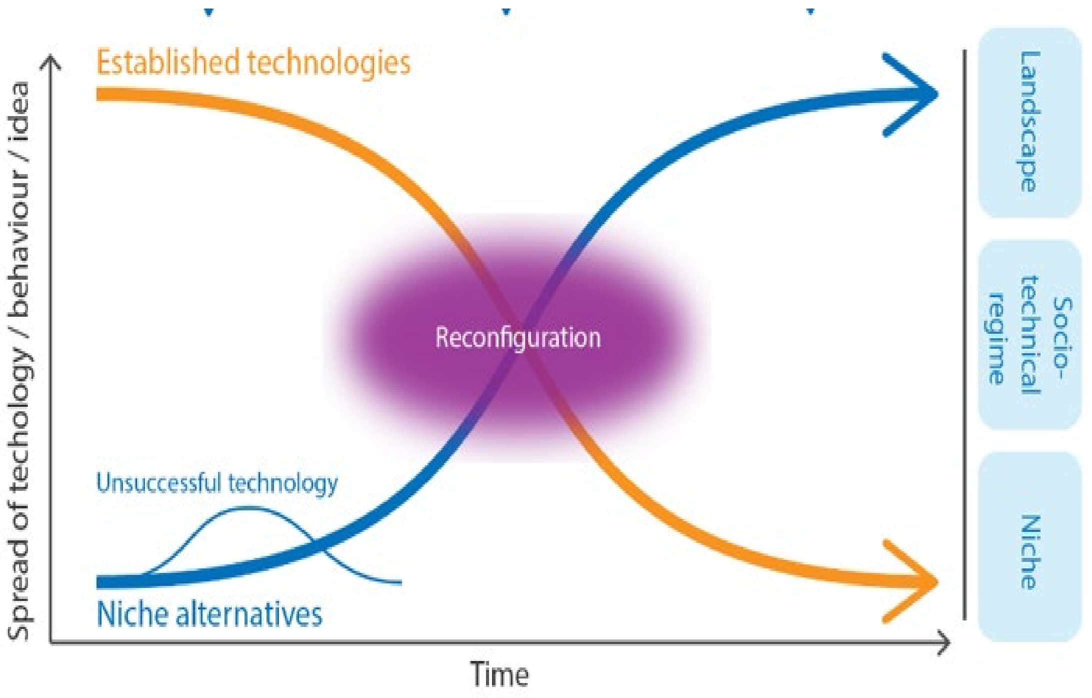
Source: Grubb, McDowell and Drummond (2017), On order and complexity in innovations systems, Energy Research & Social Science; derived from Fig.9.8 in Grubb et al (2014) *Planetary Economics*

Transitions are complex dynamic processes …

Impact on incumbent technologies / businesses initially modest, but …

…. over time may involve substantial reconfiguration of existing infra/market structures

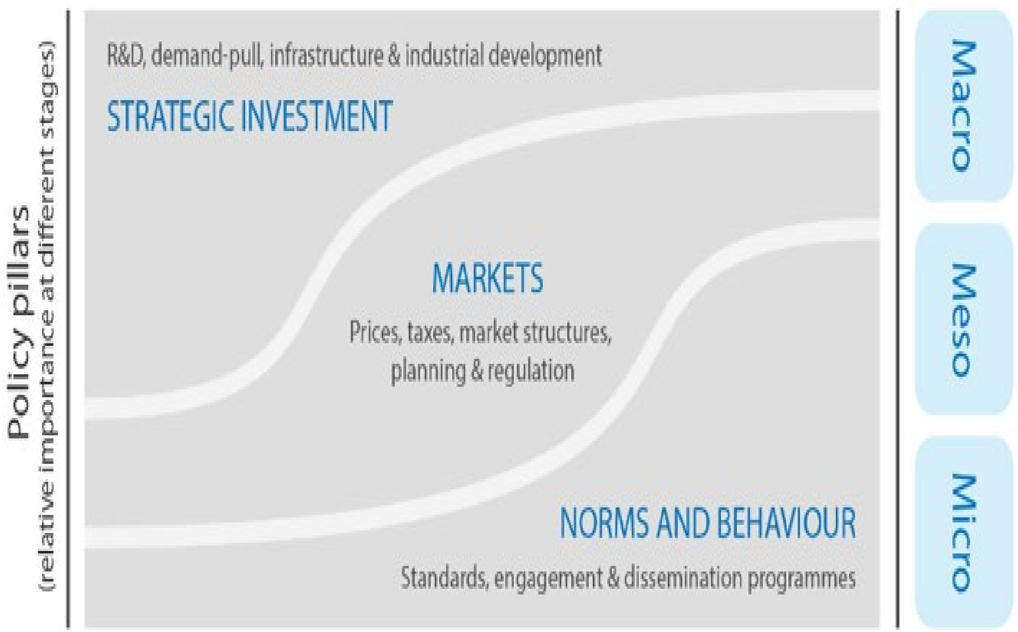
May start small, and take many years, *technology* emergence followed by *market* emergence



Source: IPCC Sixth Assessment Report – Mitigation (Chapter 1 / Technical Summary)

A mix of complementary policy instruments, evolving with transition

- Strategic Investment to foster emerging technologies and businesses, ‘leaders’
- Evolve or reconfigure infrastructure, & market structures suited to new techs
  - scale in lead markets & supply chains
  - accelerate global diffusion
- Expand with attention to standards, norms, behaviour, to support widespread adoption and ‘laggards’



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From 2015 to 2025 …

There are options available **now** in every sector that can at least **halve** emissions by 2030

Demand and services

Energy

Land use

Industry

Urban

Buildings

Transport

Many options available now in all sectors are estimated to offer substantial potential to reduce net emissions by 2030. Relative potentials and costs will vary across countries and in the longer term compared to 2030.

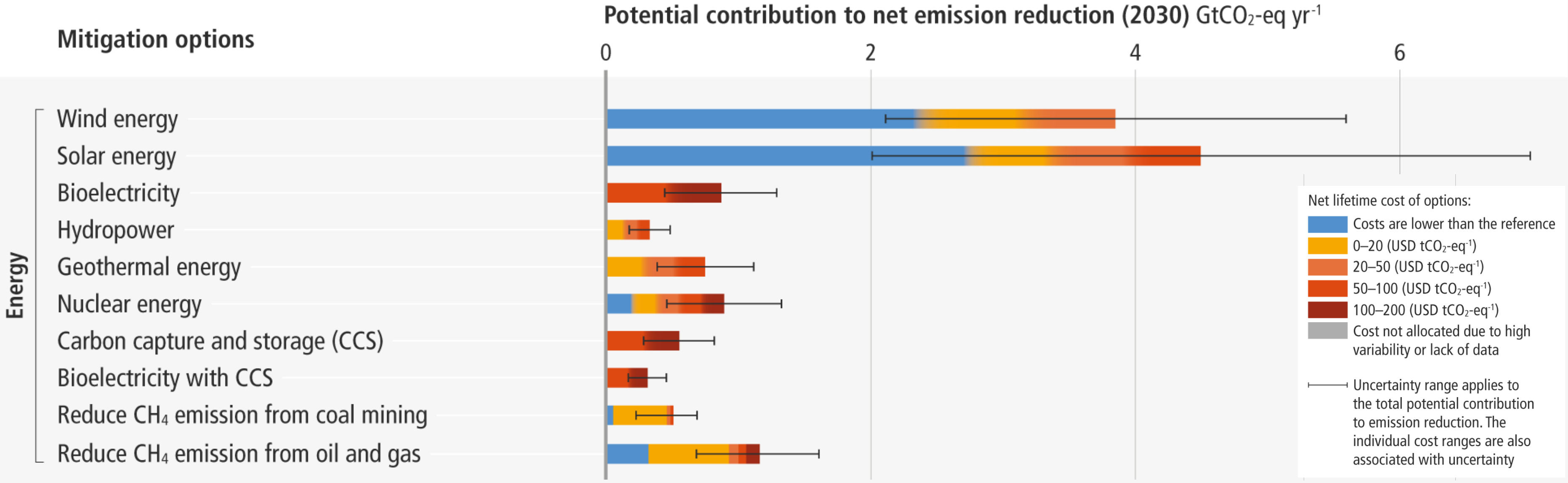


Figure SPM.7 (top panel, Energy)

Policy trends and impacts

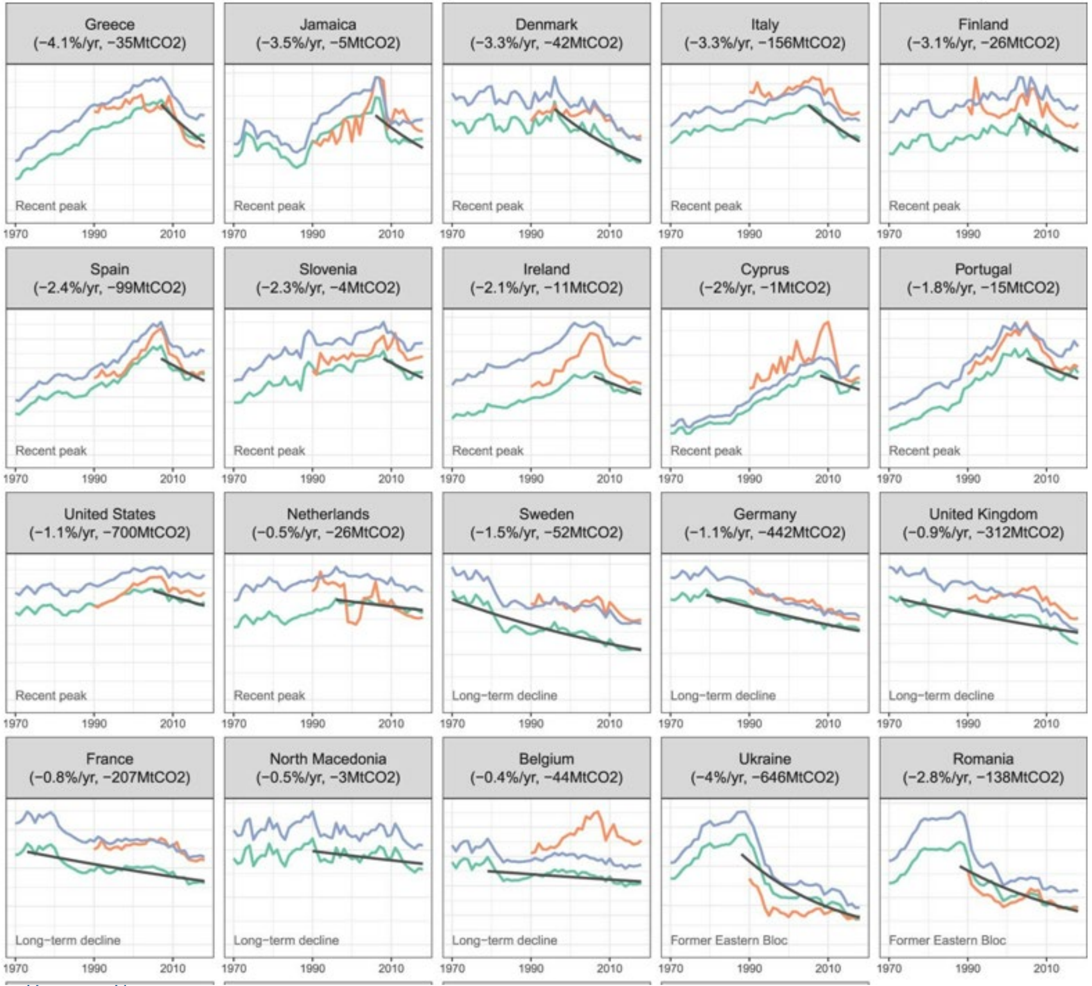
SPM B5.2 Policy Trends

- Over 20% of global GHG emissions covered by carbon taxes or emissions trading systems, although coverage and prices insufficient ..
- 'Direct' climate laws in 56 countries covering 53% of global
- Remain limited for emissions from agriculture and production of industrial materials and feedstocks
- Annual tracked total financial flows [heavily focused on mitigation] increased by up to 60% 2013/14 to 19/20)
  - are uneven, developed heterogeneously across regions and sectors, and average growth has slowed since 2018.

SPM B5.3 Policy Impacts

- In many countries, policies have enhanced energy efficiency, reduced rates of deforestation and accelerated tech deployment
- At least 18 countries have sustained production-based GHG and consumption-based CO2 emission reductions for longer than 10 years [most having Kyoto targets, exc EITs]
- Mitigation policies have led to avoided global emissions of several Gt CO2-eq/yr:
  - At least 1.8 Gt CO2-eq/yr accounted for by aggregating separate estimates for the effects of economic and regulatory instruments.
  - Growing numbers of laws and executive orders, were estimated to result in 5.9 Gt CO2-eq/yr less in 2016 than otherwise would have been.

Extract: Countries with declining CO2 and GHG emissions since peak year.



The accumulating evidence is not just about climate impacts

>24 countries with sustained emission reductions, of CO2 and all GHGs, including consumption-basis

Almost all employed ‘3 pillar’ policies, sustained since early-mid 2000s (in some cases, since early 1990s)

Lamb W.F., Diluiso F, Grubb M., Minx J.C. (2021), Countries with sustained greenhouse gas emissions reductions: an analysis of trends and progress by sector, Climate Policy, https://www.tandfonline.com/doi/full/10.1080/14693062.2021.1990831

Conclusions

‘Ignoranti quem portum petat nullus suus ventus est’ -

Lucius Annaeus Seneca

No wind favours those who don't know where they are going

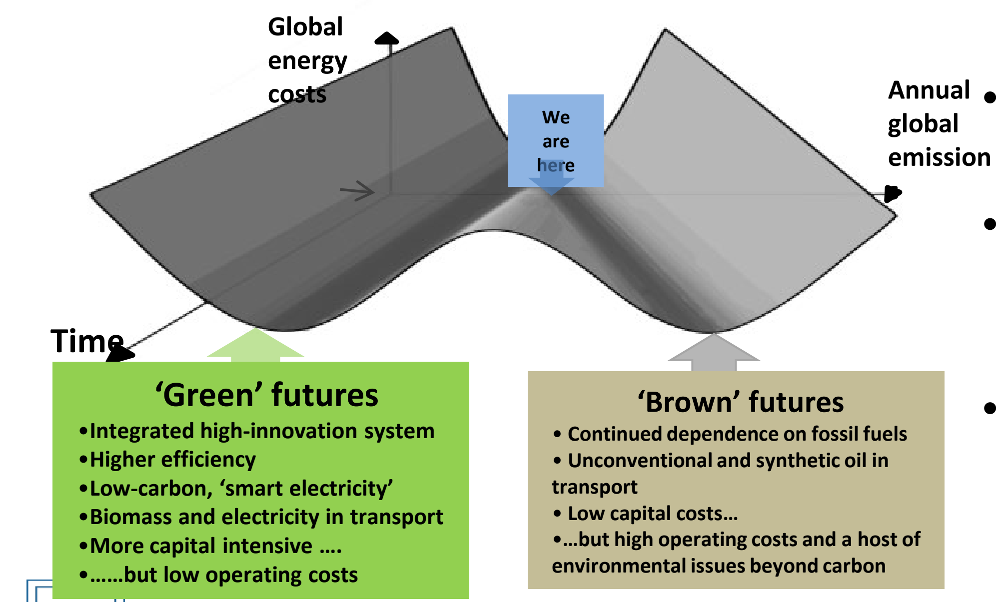


Figure 10-6: Two kinds of energy future – the carbon divide
Source: Upper panel: Gritsevskyi and Nakićenović (2000); lower panel: authors

- 21st Century energy systems will be radically different from 20th Century
- Transition is already under way, so far driven far more by non-pure-market policies
- Need the three Pillars of Policy designed as a mutually reinforcing package
- Harnessed for *industrial and development* strategies, “shifting development pathways”
- Growing social engagement and social innovation – helping to harness cleaner tech and connect the three pillars
- Clear policy direction can shift risk, lower finance costs, and increase the economic and social gains from the global transition

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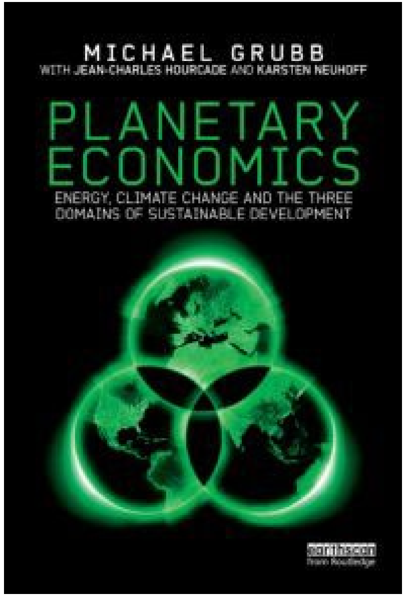

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