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Innovation Pathways, Strategies and Policies for the Low-Carbon Transition

INNOVATION AND THE LOW-CARBON TRANSITION: Insights from INNOPATHS

Presentation to the FSR Climate Annual Conference 2020

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INNOPATHS Co-ordinator

November 26, 2020
Online

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730403

Partners

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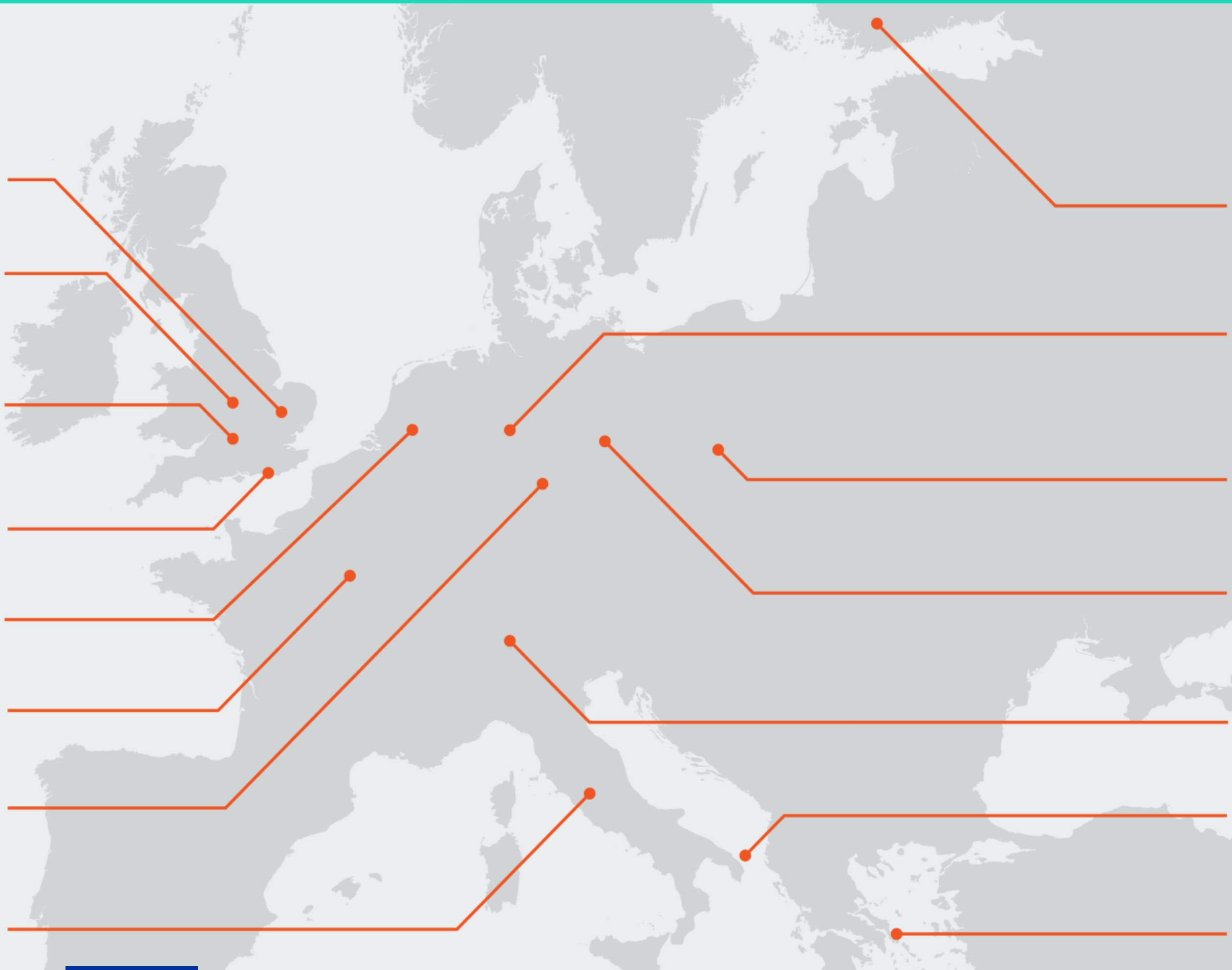

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The decarbonization challenge, 2°C

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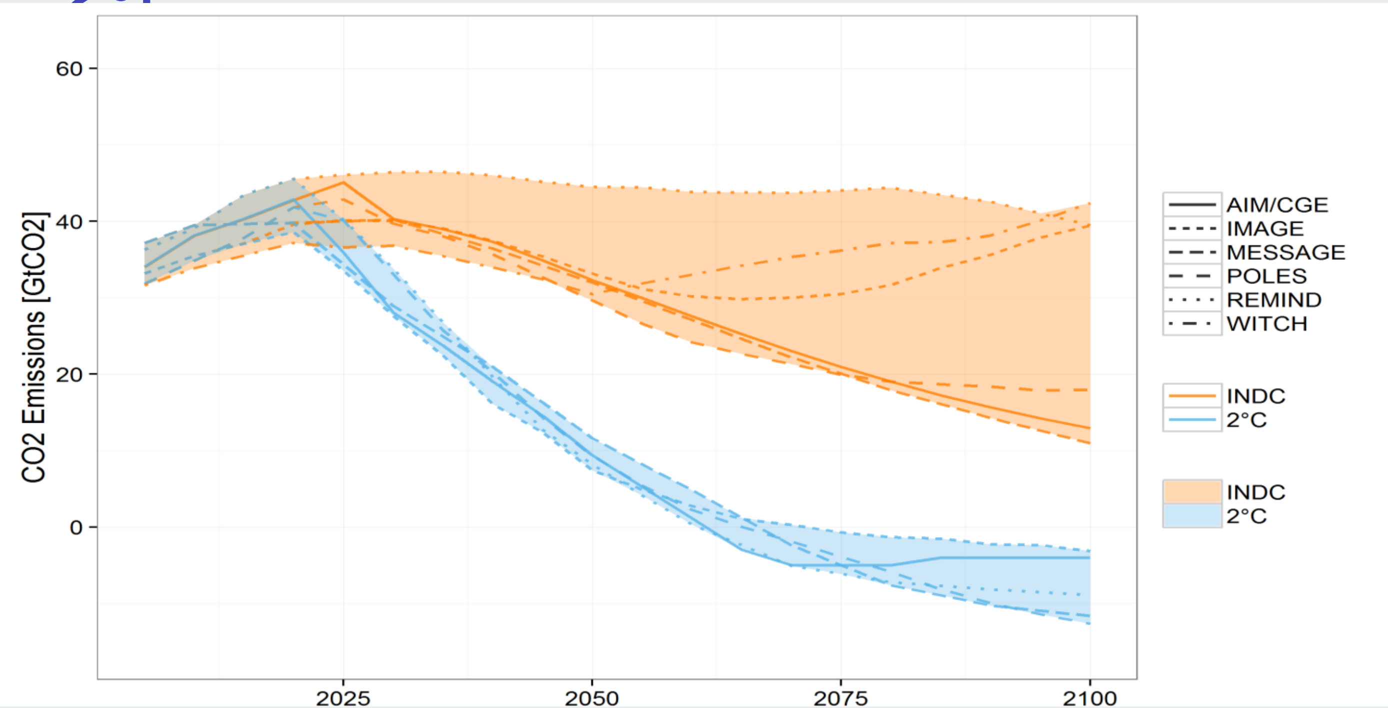

Sources: ADVANCE and CD LINKS EU H2020 projects

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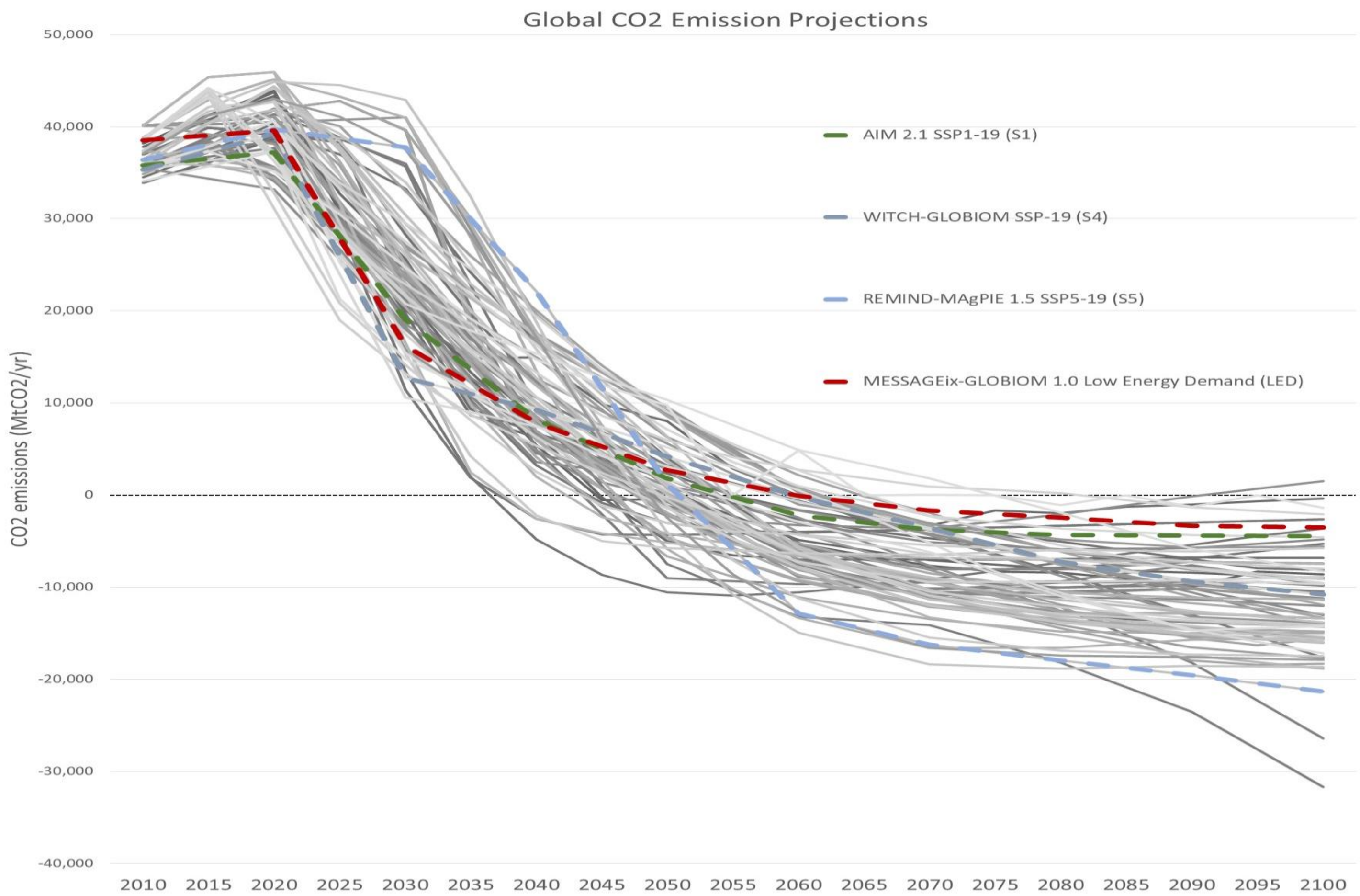

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The decarboni-zation challenge, 1.5ºC

Source: (Rogelj, Shindell *et al.*, 2018; Huppmann, Kriegler *et al.*, 2019)

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Presentation outline

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- Innovation and technology
  - Costs (the Technology Matrix Tool, learning curves, expert elicitation)
  - Historical analogues
  - Innovation framings
  - Patents and spillovers
  - Case studies
- Labour markets
- Finance
- Justice and political economy
- Scenarios
- Policy implications

Sources:
https://innopaths.eu/2020/05/13/d5-1-synthesis-report-of-the-broad-insights-and-analysis-of-wp1-and-wp2/

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What insights for policy?

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- Low and zero-carbon technologies: what are the costs, now and in the future? How low will they go, and why? Can their rate of diffusion be accelerated?
- Policy: what policies have been tried? What works?
- Scenarios: what will the world look like? How will this affect the policy approach? (teaser only here)
- Finance: how to re-direct financial flows from high to low-carbon investments by addressing the mismatch between the required and available types of finance (e.g. risk-return requirements, project vs corporate finance etc)?

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Low- and zero-carbon technologies

- Play a key role in the decarbonization process
- Crucially important for hard-to-decarbonize sectors (see case studies)
- Many are currently available, and costs decreasing
- Other (key) ones are still in development/demonstration
- Future costs are uncertain, and hard to forecast

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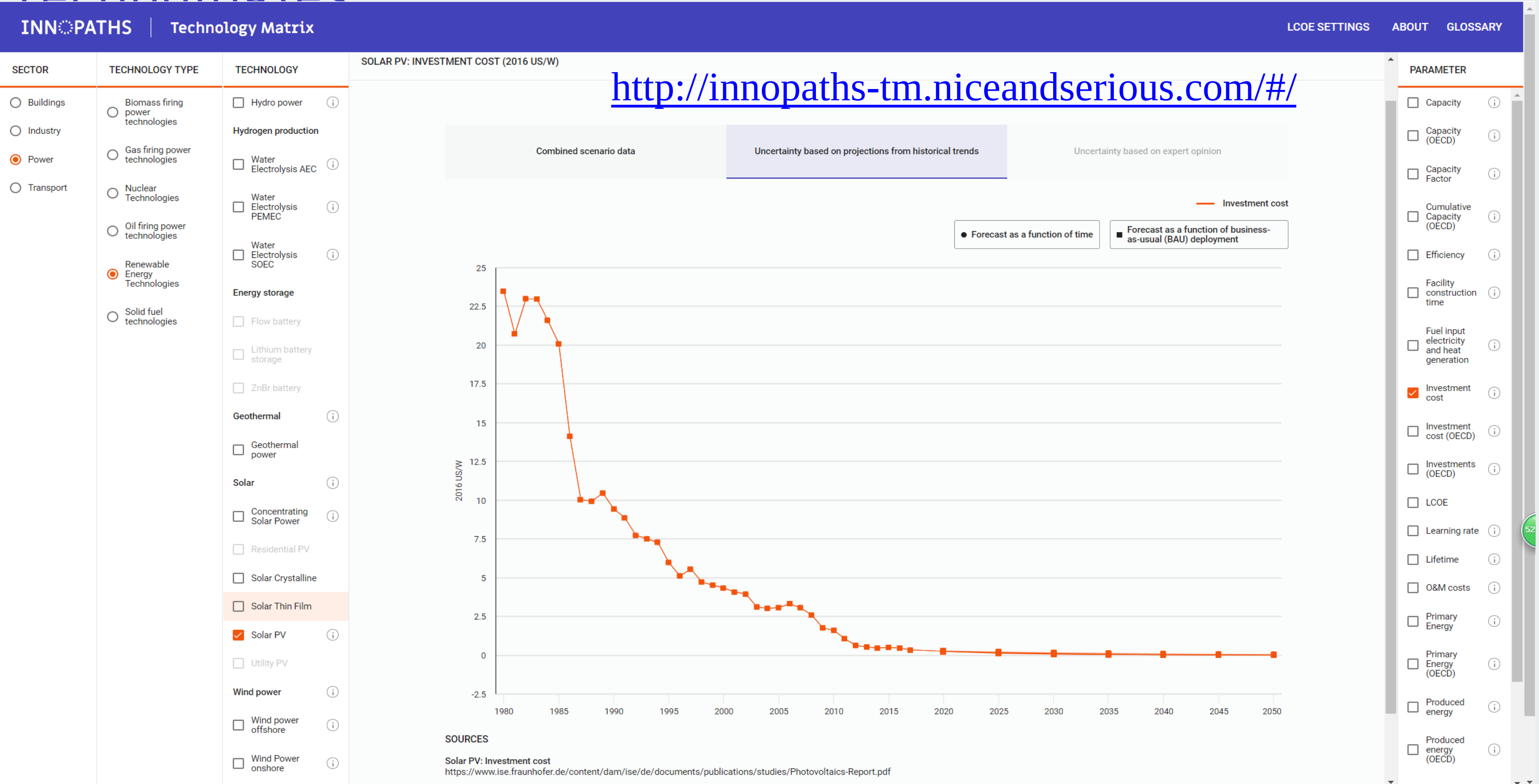
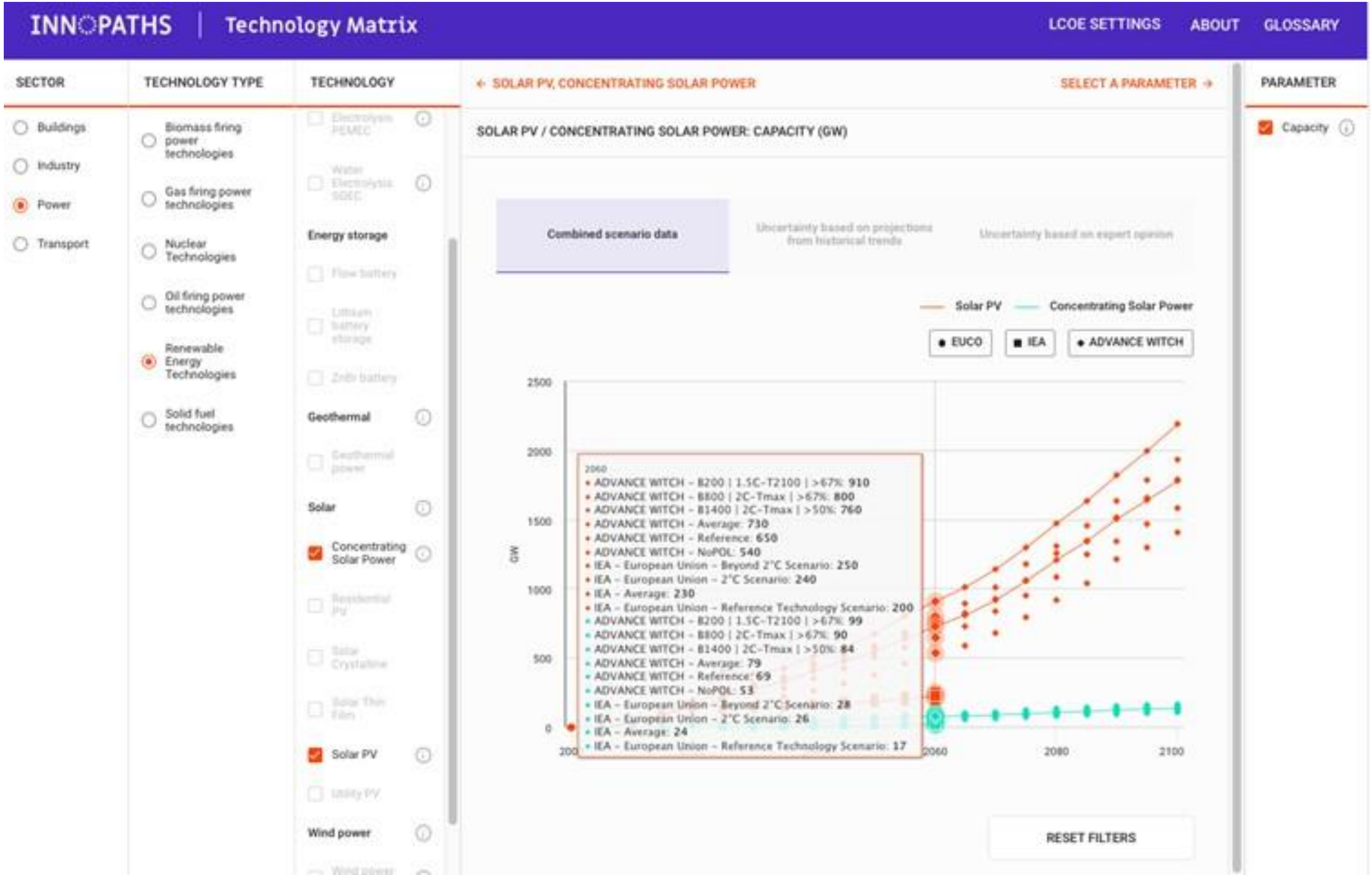
Technology matrix: wide range of technologies

http://innopaths-tm.niceandserious.com/#/

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Technology Matrix
LCOE SETTINGS
ABOUT
GLOSSARY
SECTOR
TECHNOLOGY TYPE
TECHNOLOGY
← SOLAR PV, CONCENTRATING SOLAR POWER
SELECT A PARAMETER →
PARAMETER
Buildings
Industry
Power
Transport
Biomass firing power technologies
Gas firing power technologies
Nuclear Technologies
Oil firing power technologies
Renewable Energy Technologies
Solid fuel technologies
Energy storage
Geothermal
Solar
Concentrating Solar Power
Solar PV
Wind power
SOLAR PV / CONCENTRATING SOLAR POWER: CAPACITY (GW)
Capacity
Combined scenario data
Solar PV
Concentrating Solar Power
EUCO
IEA
ADVANCE WITCH
2500
2000
1500
1000
500
0
GW
2060
ADVANCE WITCH – B200 | 1.5C-T2100 | >67%: 910
ADVANCE WITCH – B800 | 2C-Tmax | >67%: 800
ADVANCE WITCH – B1400 | 2C-Tmax | >50%: 760
ADVANCE WITCH – Average: 730
ADVANCE WITCH – Reference: 650
ADVANCE WITCH – NoPOL: 540
IEA – European Union – Beyond 2°C Scenario: 250
IEA – European Union – 2°C Scenario: 240
IEA – Average: 230
IEA – European Union – Reference Technology Scenario: 200
ADVANCE WITCH – B200 | 1.5C-T2100 | >67%: 99
ADVANCE WITCH – B800 | 2C-Tmax | >67%: 90
ADVANCE WITCH – B1400 | 2C-Tmax | >50%: 84
ADVANCE WITCH – Average: 79
ADVANCE WITCH – Reference: 69
ADVANCE WITCH – NoPOL: 53
IEA – European Union – Beyond 2°C Scenario: 28
IEA – European Union – 2°C Scenario: 26
IEA – Average: 24
IEA – European Union – Reference Technology Scenario: 17
2060
2080
2100
RESET FILTERS

Low- and zero-carbon technologies

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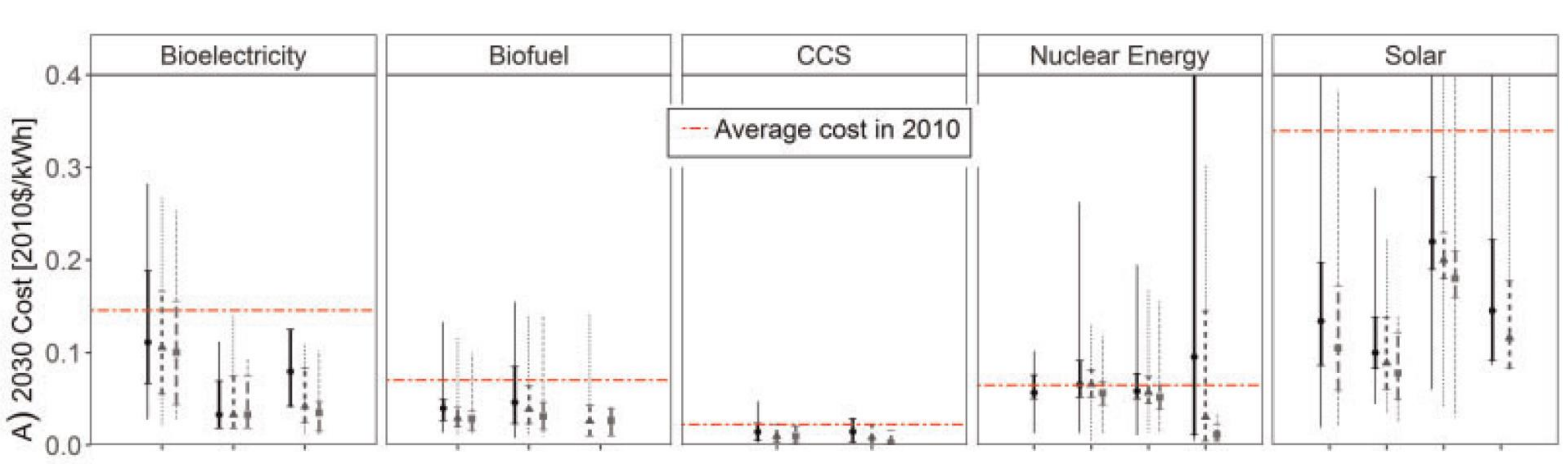
Ranges are the aggregated costs from expert elicitations (some EU, some US based) for each of the technologies for 2030 for 3 different R&D budgets (low-BAU, medium, high). The big range is min max, then 25th-75th and then the median. For nuclear costs are not expected to come down, for other technologies they are.



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Sources: Verdolini et al., 2018, REEP

Uncertainty Analysis

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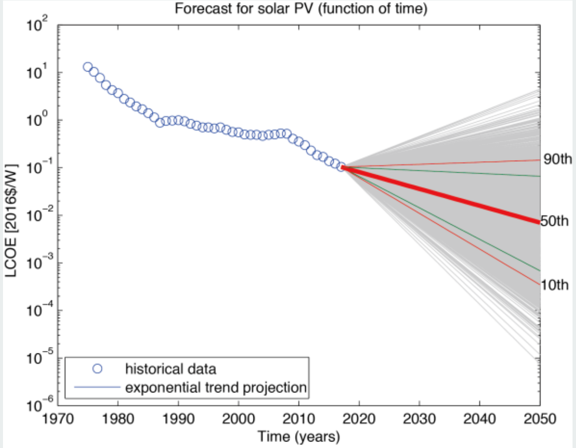
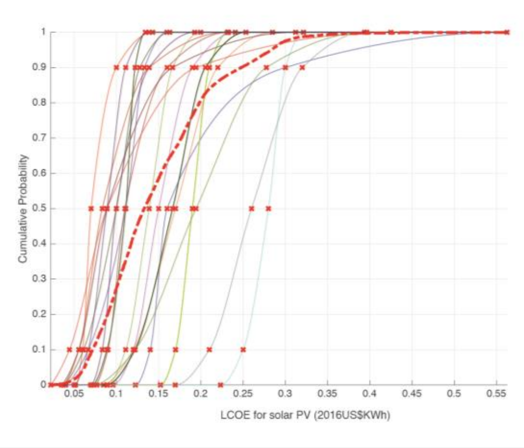
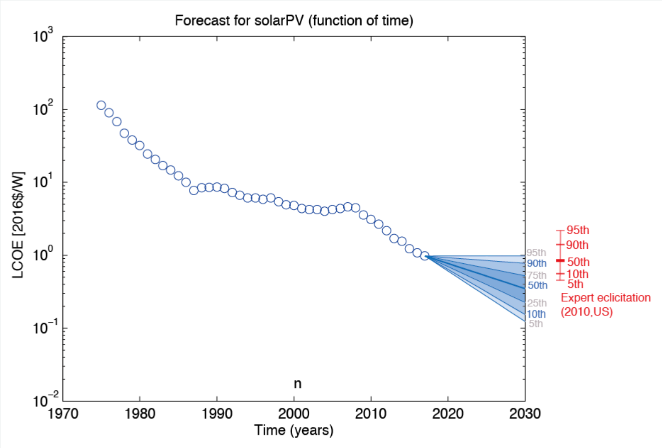
Comparing learning curve projections and expert elicitations







Statistical projection based on the distribution of learning rates

Aggregation of expert elicitations from different experts about 2030 values

Comparison of the expert elicitation ranges (in red) and the LC (in blue).

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Source: Meng et al. 2019 (under review)

Technological trajectories: past and future

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- When normalised to account for expected growth in the global economy (using GW/Decade/$T GDP) scenarios are found to be consistent with the maximum historical deployment rates of FGD.
- Heat pumps: projected rates of deployment are challenging, but none of the rates of deployment are without precedent in the countries with significant markets

	Historical analysis	Low-carbon projections
Power Generation	Flue gas desulphurisation Organic rankine cycle (ORC) turbines	Solar photovoltaics, Wind power, onshore and offshore
Buildings	District heating Heat pumps	
Industry	Iron and steel: Blast furnace/Basic oxygen furnace; Electric arc furnace; Direct reduced iron with natural gas (CH4-DRI); Continuous casting (CC); Coke dry quenching (CDQ); Top-pressure reduction turbines (TRT) Chlorine-reduced pulp Variable-speed drives and energy-efficient motors Ammonia and methanol synthesis	Iron and steel: Direct reduced iron with hydrogen (H2-DRI)
Transport	Passenger cars CNG and LPG Ethanol in Brazil	Hybrid electric and battery electric vehicles
Agriculture	Tractors Conservation agriculture	Fertiliser use Diet optimisation

Source: https://innopaths.eu/2020/05/13/d5-1- synthesis-report-of-the-broad-insights-and-analysis-of-wp1-and-wp2/

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Are *rates* of technology diffusion in scenarios consistent with the past?

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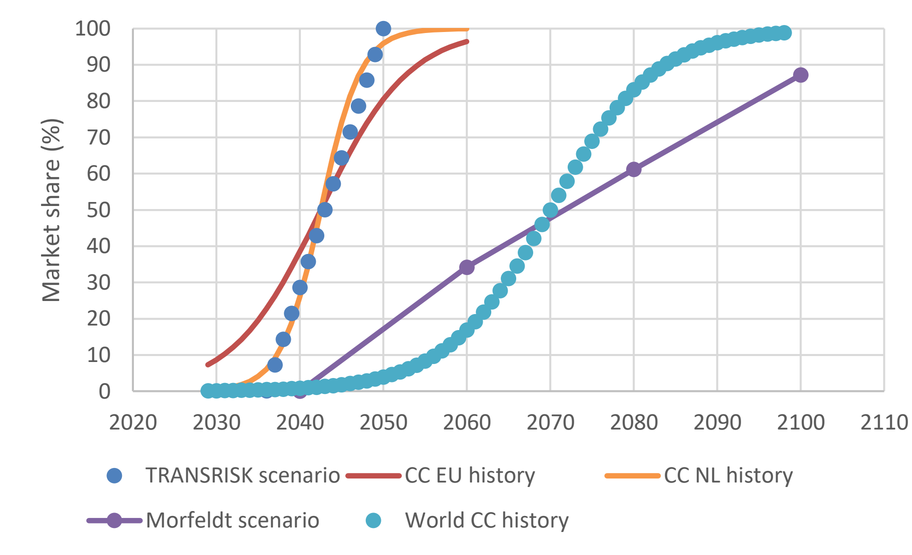
- Steel sector deep decarbonisation scenarios for Europe using H_2 reduction are very ambitious but consistent with speed of historical examples of major technological change in steelmaking
- (CC=continuous casting)



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Source: Deliverable D1.3, INNOPATHS

Are *rates* of technology diffusion in scenarios consistent with the past?

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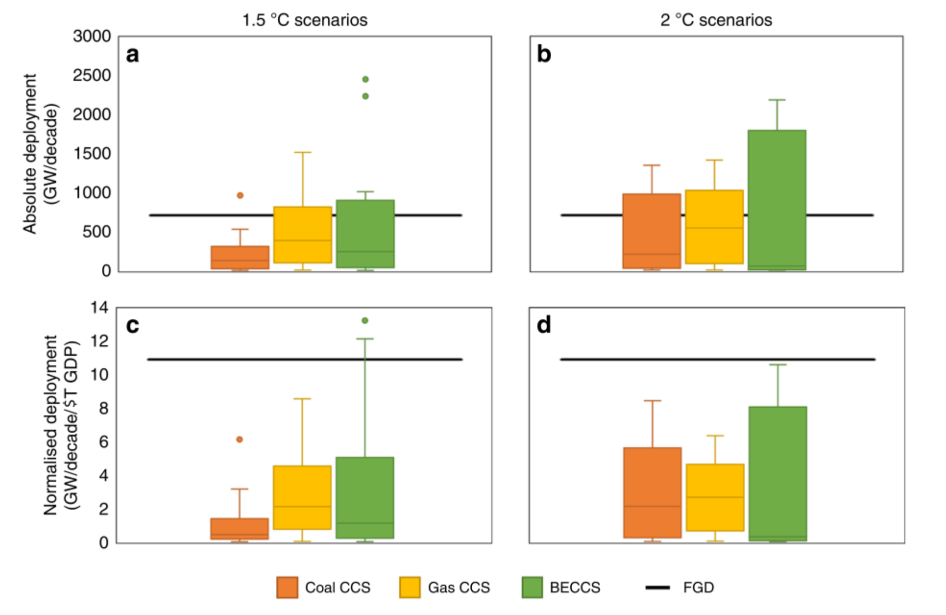
- CCS diffusion scenarios compared with historical diffusion of flue gas desulphurization, an analogous abatement technology
- Scenarios exceed historical rates on an absolute basis (top panels). When we correct for future growth in industrial capacity, scenarios are largely consistent with history



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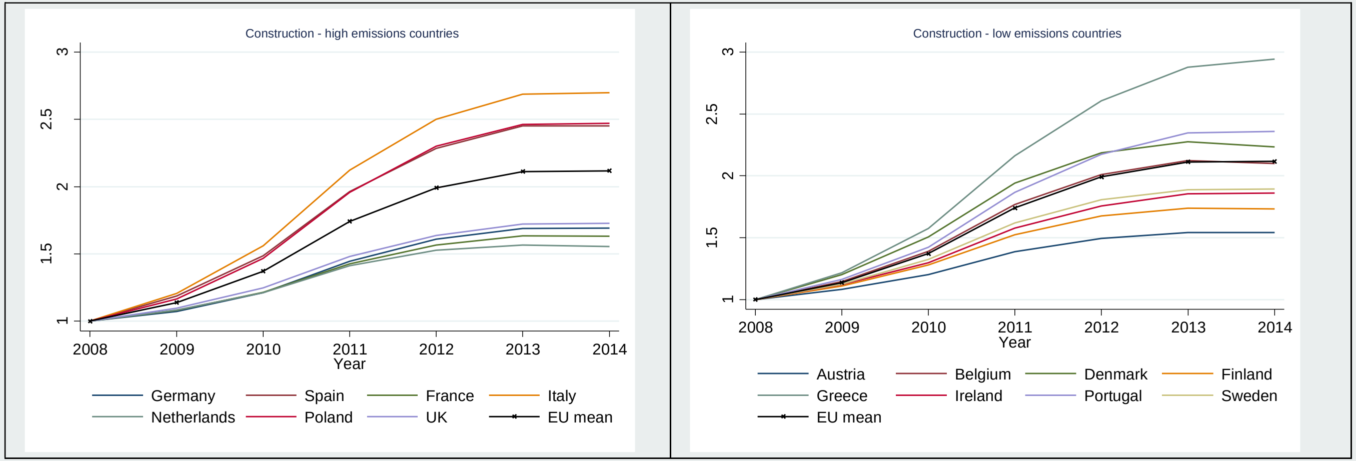
Source: Van Ewijk and McDowall 2020, *Nature Communications*

Analysis of labour markets (1)

Greenness of jobs

- The computation of greenness and skills by occupation in the US.
- The computation of greenness and green skills by occupation in the EU.
- The computation of greenness and green skills by sector in the EU member countries.



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Source: Gilli et al., Deliverable 2.5, INNOPATHS

Analysis of labour markets (2)

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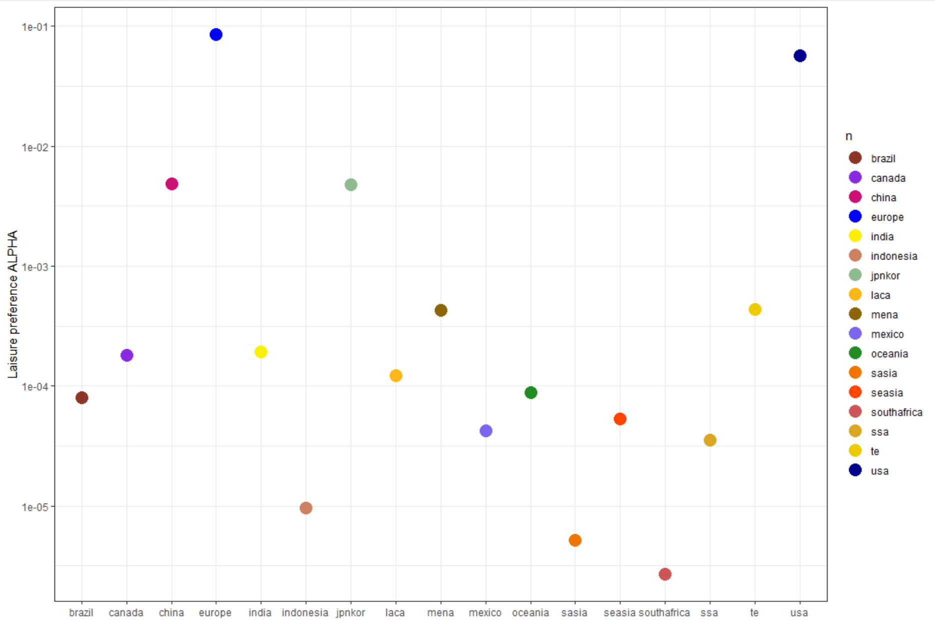
Evolution of leisure time

- Working hours have declined from about 3000 hours per year at the start of industrialisation to between 1500 and 1800 hours per year by 2015.
- This trend is projected to continue in the short term, implying higher values of leisure.
- This effect is highest in countries which have high values of leisure preference.
- Europe shows the highest value of leisure preferences followed by the USA
- This has significant implications for the evolution of energy use and GDP in IAM modelling



Source: Bosetti et al., Deliverable 2.5, INNOPATHS

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Labour markets and competitiveness

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- Environmental policy in its current and past applications have not had a significant effect on trade. There is certainly no evidence for the Pollution Haven Hypothesis. (Source: Bonacorsi and Verdolini, 2019)
- While energy price increases did not have a statistically significant effect on total employment, they have been skill-biased against manual workers and have favoured technicians. A negligible total employment effect of energy price masks significant distributional effects across both occupations and sectors. Climate policy should be accompanied by a labour market policy that retrains manual workers as technicians in order to increase its political acceptability, but such retraining is itself challenging to implement successfully. (Source: Vona 2018, *Climate Policy*; Marin and Vona 2018, *JEEM*)

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Framing of innovation

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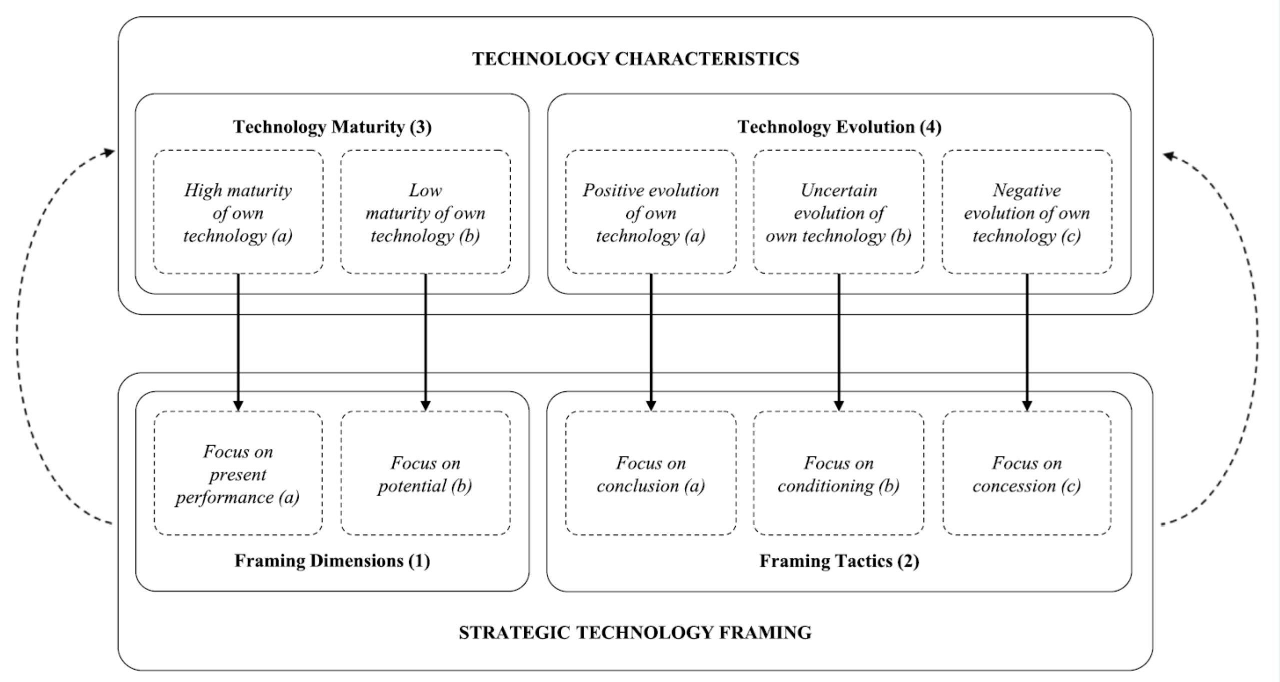
- Comparison between c-Si and thin-film PV by competing institutes
- Timescales: indefinite future, definite future, present and past
- Dimensions: potential, prospect, performance and progress
- Tactics: conclusion, conditioning and concession



Source: Hoppmann et al., 2020

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Analysis of patents

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- Since 2000 the EU RES innovation space has become more integrated, with EU RES inventors increasing their patent citations of patents from other member countries and decreasing citations of domestic inventors.
- The EU strengthened its position as a source of RES knowledge for the US, indicated by a post-2000 increase in the number of US citations of EU work, and a decrease in EU15 citations of US.
- The patterns of decreased fragmentation are peculiar to the strategic field of RES and do not apply to other comparable technologies (either from the energy field - efficient fossil-based technologies – or radically new – 3D, robot technologies, IT and biotechnologies)
- The higher integration seems to have been brought about by an intensification of the EU support for RES following signing of the Kyoto Protocol

Source: Conti et al., 2018

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Analysis of spillovers in Li-ion Batteries

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- Seven technological breakthroughs
- Four spillover mechanisms: people change their technological field or sector or moved between different scientific disciplines; interdisciplinary education, interests group work; communication or contact between individuals; access to conferences and reading of publications
- Five enablers: the structure of public funding, which provided freedom of search; the existence of interdisciplinary education and exchange programs; the management and organization of R&D groups; firms working across multiple sectors; and public and policy interest in and awareness of an issue

Source: Stephan et al., 2020 under review

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Case studies

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<table>
<tr><td>Germany</td><td>Livestock Diet Management</td><td rowspan="4">Building Envelopes for New Buildings</td><td rowspan="2">Solar PV</td><td rowspan="4">Electricity Smart Meters</td><td>Energy Management Chemical & Petrochemical</td><td rowspan="2">Battery Electric Vehicles</td></tr>
<tr><td>Italy</td><td>Biochar</td><td>Energy Management Steel Industry</td></tr>
<tr><td>Poland</td><td>Biochar</td><td rowspan="2">Wind</td><td>Energy Management Chemical & Petrochemical</td><td rowspan="2">Light Rail Rapid Transit</td></tr>
<tr><td>UK</td><td>Livestock Diet Management</td><td>Energy Management Steel Industry</td></tr>
<tr><td>EU-Level</td><td colspan="6">In depth analysis of EU-level actions/policies/approaches to each specific technology/process innovation</td></tr>
</table>

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Source: Deliverable D2.4 INNOPATHS

Case studies: High-Level Messages

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- The cost of both the cost of low-carbon technologies and the cost of supporting them plays an important role in innovation
- In most sectors, several technological configurations for decarbonisation are available.
- A successful technology transition requires the concerted action of a diversity of actors at multiple scales to shape innovation and transition dynamics.
- Value systems play a very active role in shaping innovation objectives and priorities
- European level actors, policies and institutions play a crucial role in providing an impulse for the sustainability transition.
- Successful innovation systems are those where many things “fall into place”, where different sets of actors with overlapping roles and authority push for decarbonisation.

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Source: Deliverable D2.4 INNOPATHS

Finance: how to catalyse private capital?

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- A review of 94 papers analysing the effect of policy instruments in catalysing private investments in renewables shows: Effective instruments work on both levers risk and return (risk seems even more relevant, with many renewables becoming competitive) => Policy makers should consider **risk dimension first** (typically cheaper to reduce risk than to increase returns) (Polzin et al. 2019, *Applied Energy*)

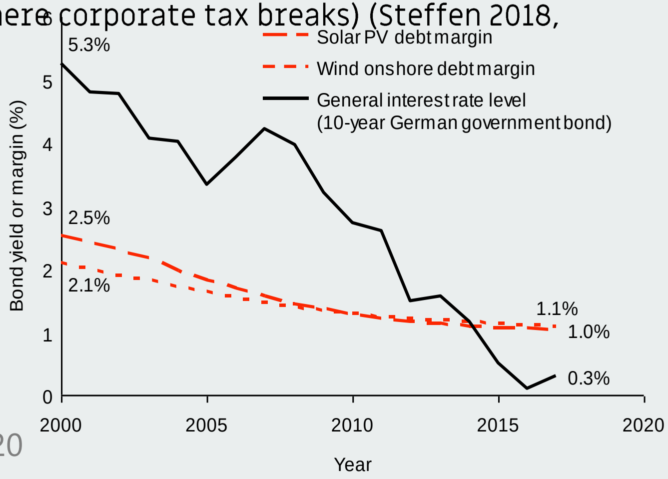
- While overall investment risk for solar PV and onshore wind has declined, there are important differences between risk types. Policy and technology risks have become relatively less important over time, while curtailment and price risks are becoming relatively more important => Policymakers need to be careful in exposing RE to wholesale markets (Egli 2020, *Energy Policy*)

- Policies that enable project finance structures (as opposed to balance sheet financing) allow fast growth of new industry of renewable project developers with **small balance sheets** => Policy makers should employ policies that **enables project finance** (such as reverse auctions or feed-in tariffs; and not mere corporate tax breaks) (Steffen 2018, *Energy Economics*)

- **Financing conditions** (cost of debt & equity, loan tenors etc.) for renewables have **greatly improved**, particularly in countries where such policies were consistently implemented. (Egli et al. 2018, *Nature Energy*) This was driven by:

    - General interest rate (IR) developments (quantitative easing) (black line in fig) => Policy makers should be aware of the **risk of rising IRs** and avoid relying on the ETS only (Schmidt et al. 2019, *Nature Sustainability*)

    - An **experience curve** in the renewable energy and financing industry reducing margins (red line in figure) => Policy makers (and modellers) should consider the long-term **cost-reducing effect**



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Green State Investment Banks

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Four key roles – well beyond capital provision

A. Capital Provision and De-risking Roles

- Direct funding for crucial gaps, concessional or commercial terms
- De-risking instruments (e.g., guarantees)

B. Educational Role

- Specialist internal expertise (e.g. accurately assessing risks)
- Financial innovation and standardization

C. Signaling Role

- SIB reputation crowding-in private equity and debt
- “SIB participation signal” with effect on financing cost

D. First or Early Mover

- Early movers with respect to new technologies (in the country), new deal structures, new manufacturers and developers

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Source: Geddes et al., 2018, *Energy Policy*

Political economy, disruption and injustice

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- Decarbonisation is bound to give rise to major distributional effects, some of which will be perceived as injustices.
- Vulnerability indicator: see next slide
- Justice: distributional, procedural, cosmopolitan, and recognition; spatial and temporal
- Four key technologies: nuclear in France and Germany, solar PV in Germany, smart meters in UK, EVs in Norway

https://innopaths.eu/2020/05/13/d5-1-synthesis-report-of-the-broad-insights-and-analysis-of-wp1-and-wp2/

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Relative vulnerability to decarbonisation across European NUTS2 regions

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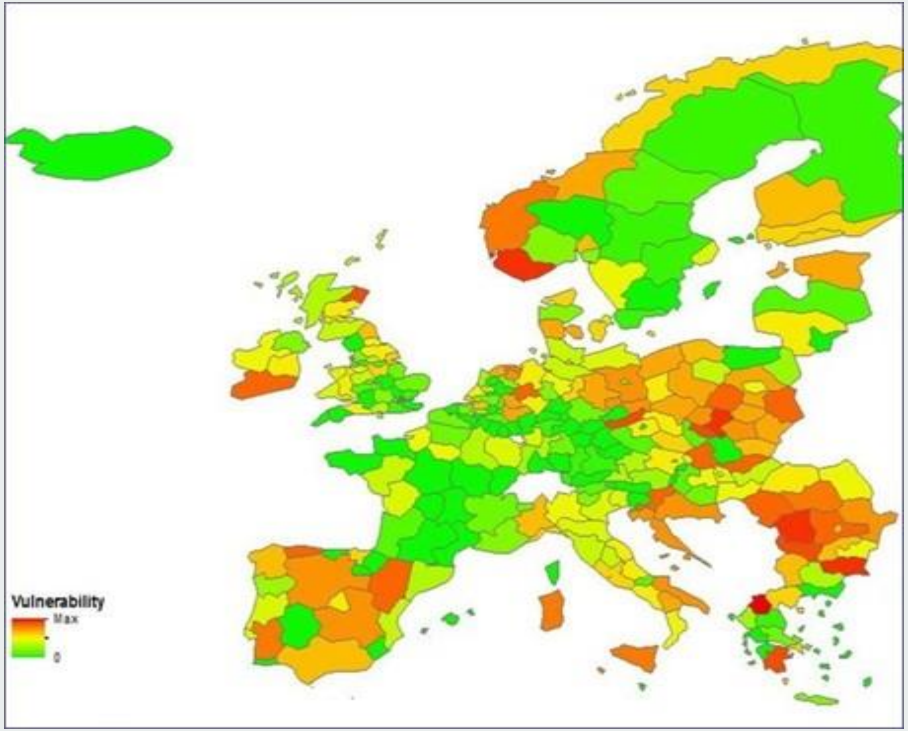
- Vulnerability indicator: carbon-intensive industry (fossil fuel extraction and processing, and internal combustion engine manufacture) that declines in decarbonisation scenarios, low education, high unemployment (high pre-existing rates), low levels of education



Source: McDowall et al., 2019

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Whole systems energy justice impacts of four European low-carbon transitions

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- 120 ‘injustices’
- E.g. public financial support for the uptake of EVs, which currently tend to be more expensive than internal combustion engine (ICE) vehicles, favours richer rather than poorer households

Spatial

Macro (global)	• Mineral extraction processes • Transportation of materials • Labor conditions • Global supply chains	• Rising energy demand • Impact on other countries’ policies	• Rising global waste • Geopolitical issues
Meso (national)	• Increase in subsidies leading to raised taxes • Carbon footprint of installations • Diversion of funds from other sectors	• Inequality of benefits • Increased vulnerability and inequality	• Waste • Costs of disposal • Recycling of old materials
Micro (local)	• Disruption of ecosystems • Diversion of funds from other sectors • Loss of local jobs in old systems • Health risks to workers in factories	• Local pollution • Exposure to local risks • Urban-rural divide	• Legacy of local pollution
	Production/ distribution stage	Consumption stage	Disposal/ recycling stage

Temporal

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Source: Sovacool et al., 2019, *Global Environmental Change*

Core Scenarios – based on co-designed narratives

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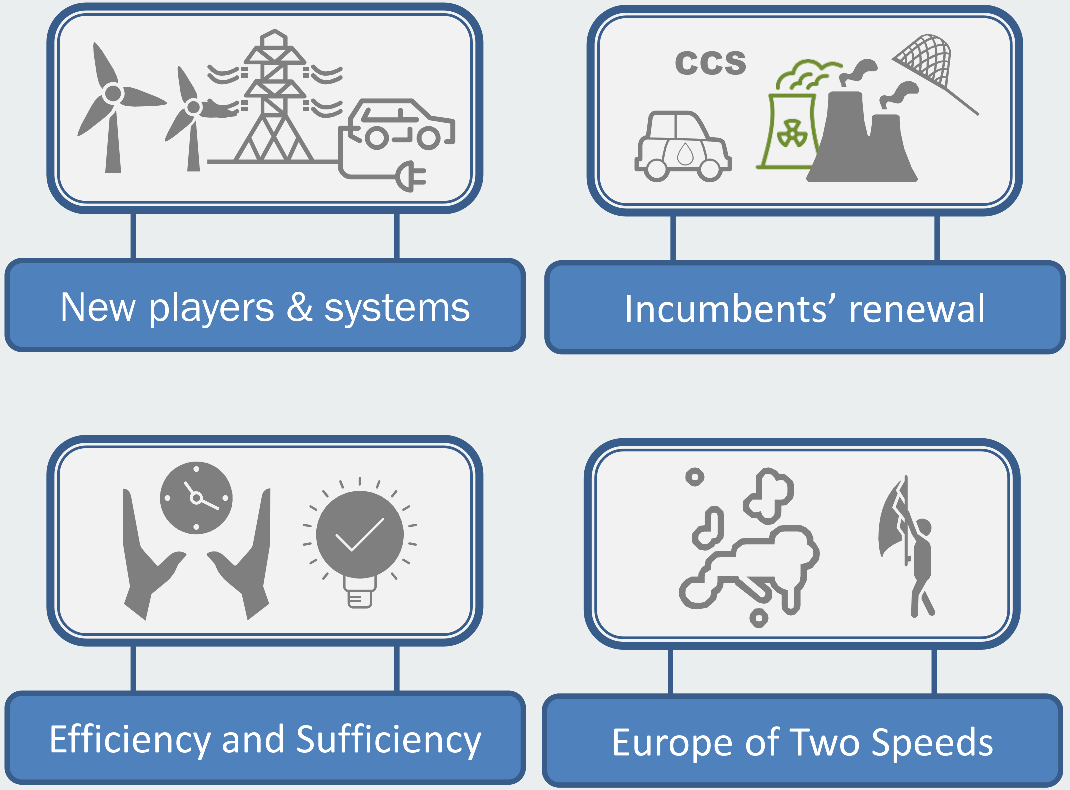
IR: big energy companies switch to supply of low-carbon energy, with large-scale deployment of renewables, CCS, synthetic fuels from hydrogen.

NPS: Rapid innovation with new businesses providing new technologies and services. Energy services are largely electrified, largely through wind and solar, with flexible demand, grid expansion and large-scale storage..

E&S: substantial behaviour and lifestyle changes, with more efficient energy use, low-carbon lifestyles, reduced consumption in an increasingly circular economy.

E2S: different MS rates of decarbonisation using different technologies and policies, in a world of competition and conflict.



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Policy implications

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- **Well-designed climate and energy polices** needed to promote decarbonization
- These policies also have **technological, economic and social outcomes** (e.g. competitiveness, wages).
- Debate on **trade offs and policy effectiveness** and is very much open and lively, complex to synthesize
- What policies have been introduced? Which are most effective?

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Decarbonisation Policy Evaluation Tool

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The need

- **Evidence to support policy decisions about alternative instruments to achieve various goals related to the energy transition**

The goal

- An **integrated tool** with information about the impact of **different policy instruments** on **several outcomes** of societal interest, including an evaluation of the **strength of evidence**

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Decarbonisation Policy Evaluation Tool: What's in?

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1. **To date**: Available evidence regarding 10 different policy instruments that can shape aspects of the transitions to a low-carbon economy
2. Evidence analysed in terms of 7 different criteria used to understand the impact of the policy instrument on environmental, technological, cost, competitiveness and social outcomes
3. The strength of the evidence: by paper and aggregated by policy
4. The context for the evidence to help interpret its possible applicability elsewhere

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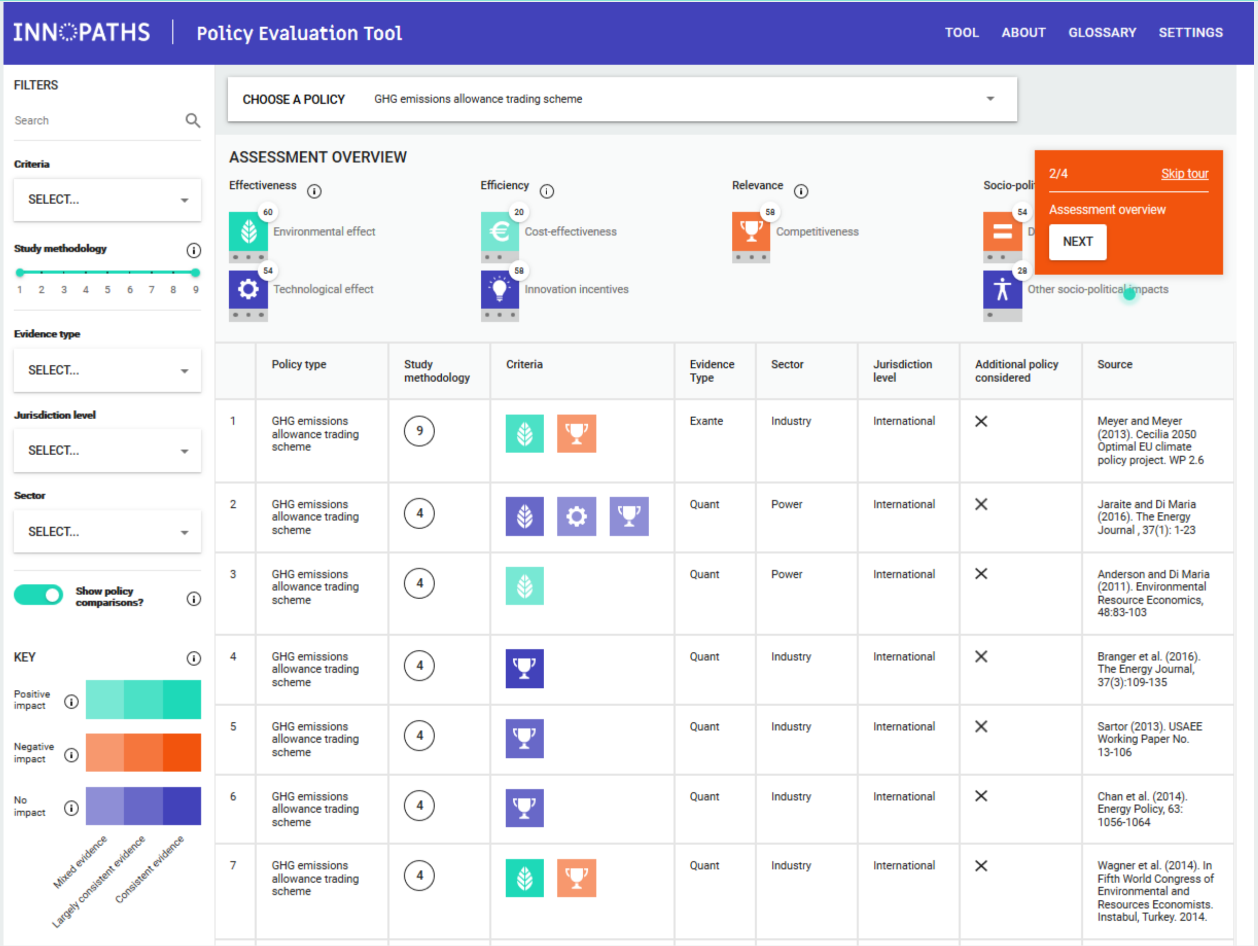

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Decarbonisa-tion Policy Evaluation Tool

Source: Deliverable D2.6, INNOPATHS and Penasco et al.. 2020, under review

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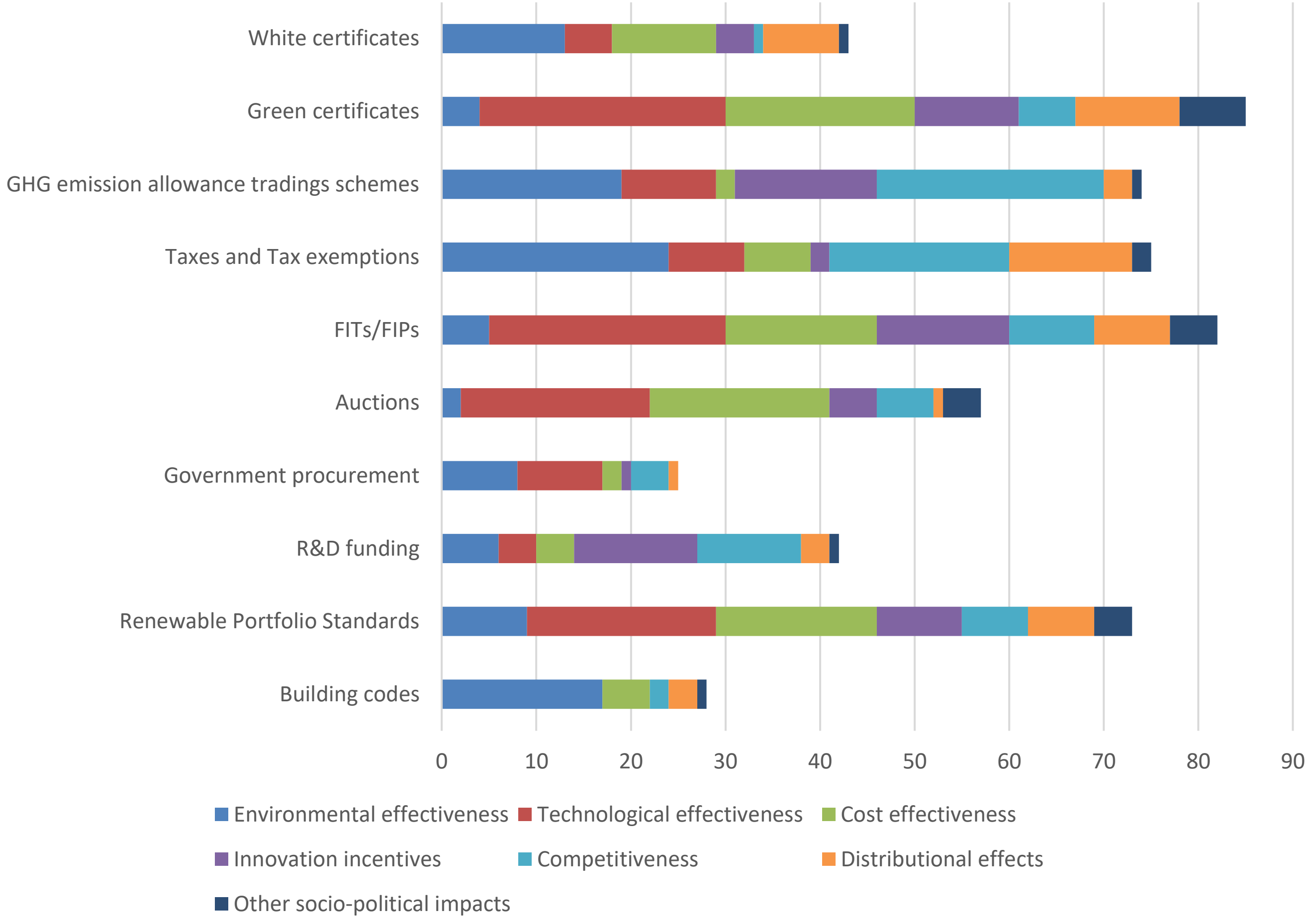

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Decarbonisa-tion Policy Evaluation Tool

Preliminary results

Source: Deliverable D2.6, INNOPATHS and Penasco et al., 2020, under review

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