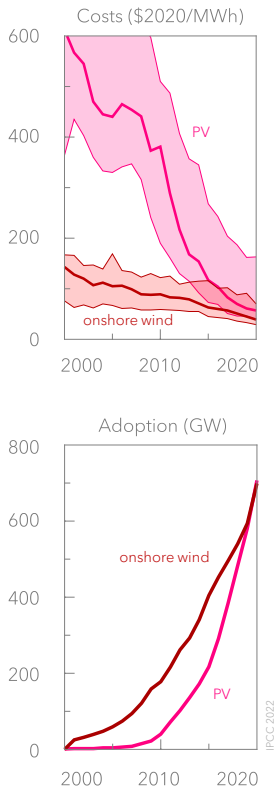
Explainer

Technology Deployment

Being able to develop and deploy climate technologies at time will be crucial for decarbonization strategies to succeed. How fast is enough? Which dynamics may be observed?

Advancing at the right speed

Since the very first operating solar cells, it took almost 70 years for photovoltaics to deploy as a proven large-scale energy technology. A very long, still ongoing evolution resulting from both technical and non-technical factors. The Climate Tech ecosystem comprises a variety of technologies that are at different **levels of maturity** *(see box)*, and therefore will be deployed over different timescales. Some sectors, such as heavy industry (steel, cement…) are particularly hard to decarbonize without technologies that are currently still at early stages of development. Getting those nascent technologies to the relevant scale within the very tight timeframe for climate action challenges the usual mechanisms and patterns of **innovation**.



A variety of action levers

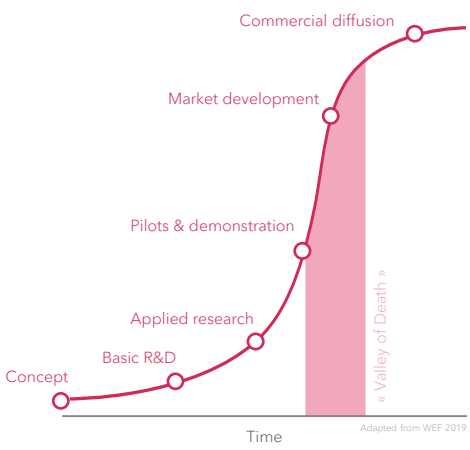
Technology deployment can be stimulated by following two main approaches, namely increasing new knowledge and financing research activities (**technology-push**) or providing the conditions for the creation of a favourable market (**demand-pull**). Companies, governments, institutions and investors can play different roles at the various stages of the process. Policy instruments can provide a steady regulatory framework and contribute to financing R&D along with private investments. More specifically, drivers of technological change include:

Spillovers: benefits (knowledge) from other technology areas (e.g. semiconductors and PV)

Economies of scale: cost advantages observed with rising size/market maturity of a technology

Learning-by-doing: accumulation of knowledge from direct experience with the technology

Key attributes of a technology that can accelerate its adoption: small unit size, modularity, minimal infrastructure changes, valuable services…



Renewable energy

Over the last two decades, wind and solar PV have been deploying at speeds that exceeded all expectations – a combined result of strong government support, economies of scale, learning-by-doing and continuous technological innovation. ▲

Deployment times

Estimating the deployment times of future technologies is particularly difficult. In its Sustainable Development Scenario, the IEA finds out that faster deployment speeds than what has been observed until now may be a necessity for reaching climate targets in time. Certain relevant parameters and attributes can either slow down (lock-ins, behavioural and institutional barriers) or accelerate (small size, modularity, drop-in capacity) the diffusion of technologies to market scale, as highlighted by the examples here (estimations from IEA 2020). ▶

Innovation timeline

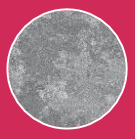
An s-curve provides a gross approximation for representing the evolution of a technology from the concept phase to large-scale diffusion and market penetration. In reality, innovation processes follow a trial-and-error principle – phenomena such as spillovers can lead to strong nonlinearities, while technical and financial risks are maximal in the so-called « Valley of Death ». ◀

Technology Readiness Levels (TRLs)

The **TRL** is an indicator commonly used by researchers, companies or investors that reflects the maturity of a technology at a given time. The TRL scale provides a uniform base that allows to compare technologies that are very diverse. Given that technologies at different development stages have different needs in terms of R&D, fundings or support policies, TRLs can assist decision making, helping to manage risks or prevent premature application. The TRL scale presented here, along with some illustrative examples, is a version extended by the IEA to account for larger-scale implementation, which is often a crucial condition for clean (energy) technologies to reach their full mitigation potential.

Concept	1	Idea
	2	Application formulated
	3	Concept validation
Prototype	4	Early prototype
	5	Large prototype
	6	Full prototype at scale
Demonstration	7	Pre-commercial
	8	First of a kind commercial
Early adoption	9	Commercial operation
	10	Integration needed at scale
Maturity	11	Stability reached

Prototype
Direct air capture

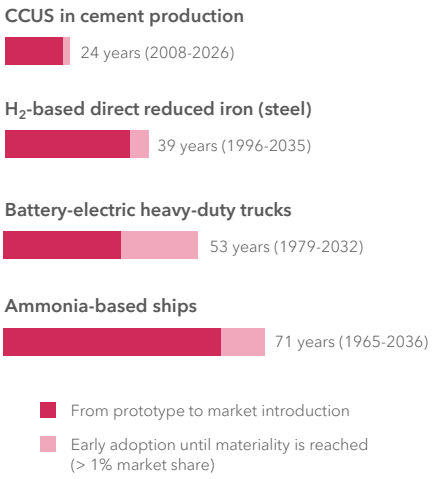


Demonstration
Low-carbon cement

Early adoption
Off-shore wind

Mature
Electric trains

Adapted from IEA 2020



References: IEA 2020, Special Report on Clean Energy Innovation / IPCC 2022, 6th Assessment Report, Working Group III / WEF 2019, Fostering Effective Energy Transition

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