SUPPLEMENTARY INFORMATION

Data Compilation and Evidence Gathering

The following table gives an overview of the mentioned and additionally relevant studies and how we used them for our approach and how it therefore differs from the other studies:

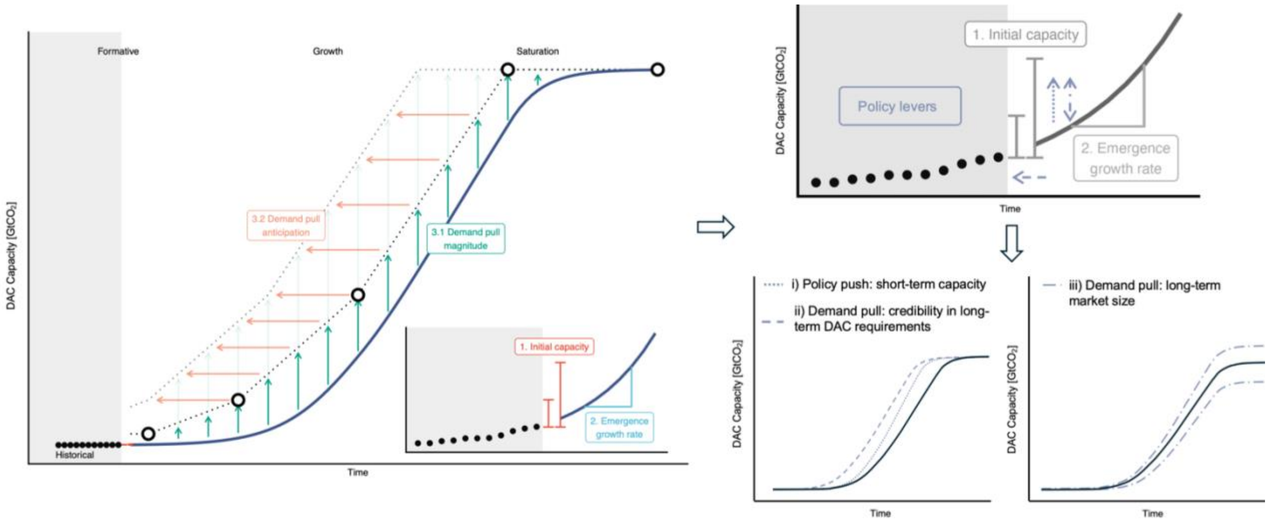
SI_Table 1: Overview of different studies and our approach to complement and combine them.

Available Studies	Usage for our approach	Differences to our apporach
Odenweller et al. (2022)[17]	Adapted and elaborated logistic model.	Focus on green hydrogen with distinction of conventional (wind energy and solar pv) and unconventional (fast growing historical technologies) growth rates and a fixed demand pull for the hydrogen market in 2050.
Roberts and Nemet (2024)[16]	Identifiction and database of analog technologies for liquid DAC (ammonia synthesis, carbon capture & storage (CCS) and LNG).	Instead of additionally using LNG and CCS as analog technology, we added them only as sensitivities and replaced the analog CCS with wind energy, firstly to include solid DAC and secondly to have an optimistic growth rate scenario for comparison. The analog LNG served accordingly as a pessimistic growth rate scenario.
Edwards et al. (2024)[5]	Recognition of their approach.	Our model includes extended probabilistic elements for realistic market development and a more systematic choice of analogs. Methodological approach based on IAMs.
Nemet et al. (2023)[56]	Growth rate data of LNG from HATCH database.	Methodological approach based on IAMs, focusing mainly on DACCS and don't model policy uncertainty in their framework.

SI_Table 2: Overview of all relevant databases and references for performing the analysis.

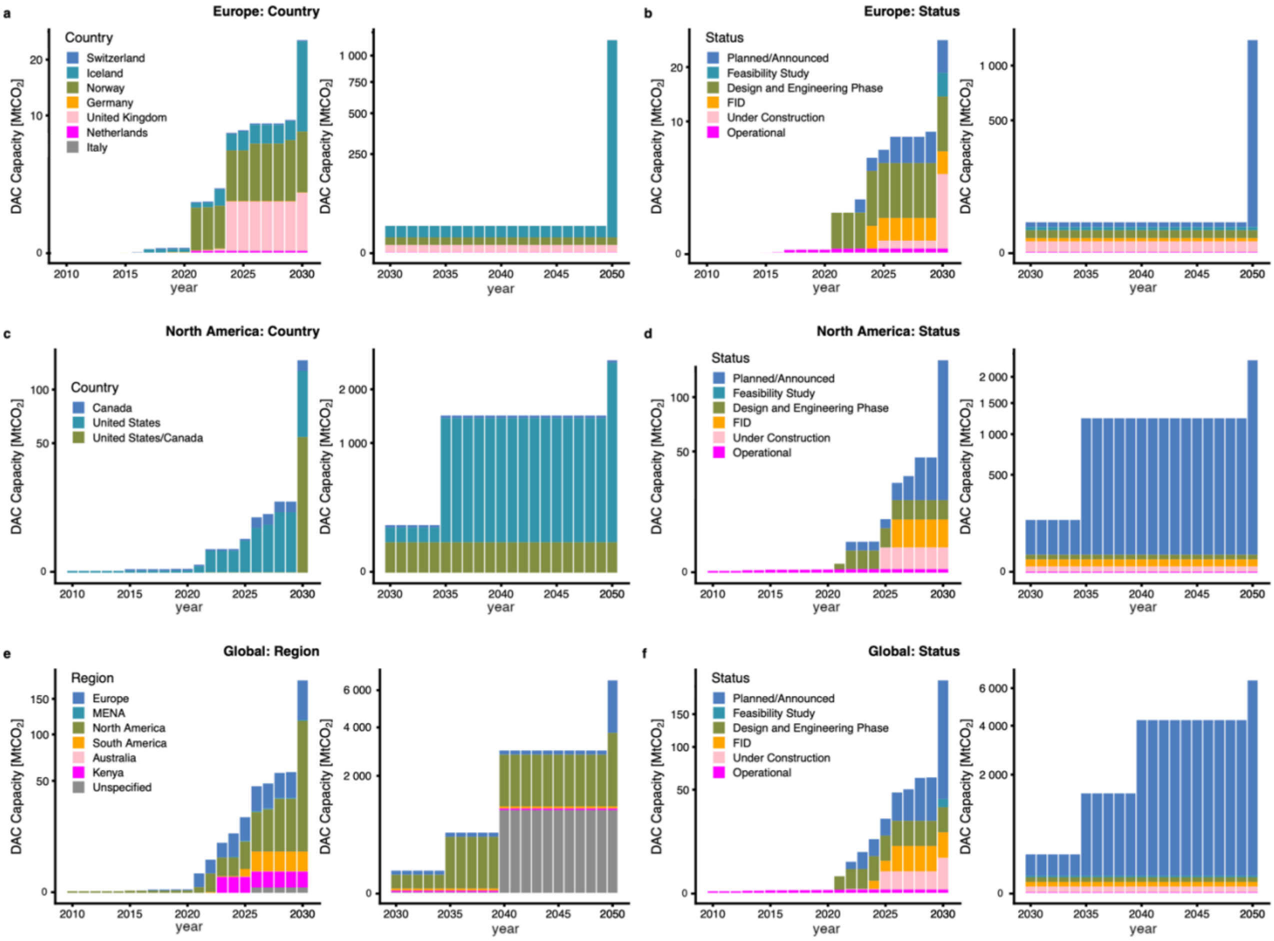
Type of Information	Description	References
DAC projects database	Created database of all historical and future announced DAC projects (chapter 2.1)	[13,19,20,41,47,57–59] Excel File 'Capacity DAC Projects Database 2024.xlsx'
Baseline growth rate (ammonia synthesis) and pessimistic growth rate Sensitivity (LNG)	Growth rates based on most suitable analog technology to DAC (chapter 2.3)	[16]
Optimistic growth rate sensitivity (wind energy)	Growth rates based on market-driven capacity data for wind energy (chapter 2.3)	[55]
Long-term market size	Estimation of market size range for DAC in 2050 based on climate mitigation scenarios	[20,49,50]
Code Availability and Additional Excel Files	Provided Code and Excel files for the mentioned databases and calculations	GitHub

Modelling Technology Diffusion Pathways



SI_Visual 1: Illustration of the modified S-curve modeling by Odenweller et al. (2022) (left) based on the uncertain parameters and the inclusion of policy levers for DAC capacity deployment. The uncertain parameters include the initial capacity (1.), as well as its modification by (i) short-term capacity boosts until 2030. Secondly, these also include the growth rate (2.) and, thirdly, the modified demand pull due to (ii) long-term demand credibility and (iii) minimum long-term demand security (bottom right). The black filled dots and the shaded area reflect the historical DAC capacity. The larger black circles represent the deployment projections defined in Odenweller et al. (2022), and define the demand pull magnitude (3.1). The gray dotted line represents the demand pull defined by a linear function between the deployment projections. The demand pull magnitude (3.1) is represented by the green arrows and has been adjusted in our analysis by the modified demand-pull of the long-term market size (iii). The orange arrows represent the anticipation (3.2) and the demand pull over time. In our analysis, we defined this demand pull anticipation with the credibility for long-term DAC requirements (ii). The close-up in the formative phase shows the uncertainty of initial capacity due to DAC using the simplified representation of error bars. The minimum is defined as the cumulative sum of projects already in operation or under construction and the maximum as all cumulative projects, including those that are uncertain due to their development status. The lines colored in grey-blue show the effects of the policy levers (i-iii) introduced, so that (i) causes the example path to rise more steeply due to the increase in capacity, (ii) pushes the example path forward in time as (3.2) and (iii) defines possible market growth and thus random deployment projections for the example path. The S-shaped line represents a single example path in the resulting feasibility space.

Historical and Future Announced DAC Projects



SI_Visual 2: Overview of historical, future planned and announced DAC projects, whereby (a-d) show projects of the regions Europe (a) and North America (c) based on the countries and their project development status (b, d). Furthermore, (e-f) show a global project overview based on regions (e) and their development status (f). Due to the discrepancy in project capacities, the plots were split between 2010 to 2030 and 2030 to 2050 and compressed on the y-axis. The decommissioned projects were not included in the figure due to their marginal quantity.

Uncertain Parameters

SI_Table 3: Overview of uncertain parameters for the base case and the case with additional technology policy as well as the considered policy levers regarding the baseline emergence growth rates of LNG and wind energy.

<table>
<tr><th rowspan="5"></th><th colspan="15">Uncertain parameters</th></tr>
<tr><th colspan="11"></th><th colspan="4">Policy levers</th></tr>
<tr><th colspan="3">Initial capacity (2030)</th><th colspan="4">Emergence growth rate (LNG)</th><th colspan="4">Emergence growth rate (wind energy)</th><th>i) Policy push: short-term capacity (factor)</th><th>ii) Demand pull: long-term credibility</th><th colspan="2">iii) Demand pull: Long-term market size</th></tr>
<tr><th>Min</th><th>Mean</th><th>Mean</th><th>Min</th><th>Mean</th><th>Max</th><th>σ</th><th>Min</th><th>Mean</th><th>Max</th><th>σ</th><th colspan="2"></th><th>Min. Value</th><th>Max. Value</th></tr>
<tr><th colspan="3">[$MtCO_2$/a]</th><th colspan="4">[%/a]</th><th colspan="4">[%/a]</th><th>[-]</th><th>[%/a]</th><th colspan="2">[$GtCO_2$/a]</th></tr>
<tr><td>A) Base case</td><td>4.8</td><td>8.8</td><td>76.0</td><td rowspan="2">0.0</td><td rowspan="2">3.8</td><td rowspan="2">6.8</td><td rowspan="2">1.0</td><td rowspan="2">0.0</td><td rowspan="2">20.0</td><td rowspan="2">42.0</td><td rowspan="2">6.3</td><td>1.0</td><td>5.0</td><td>0.0</td><td>5.1</td></tr>
<tr><td>B) With technology policy</td><td>48.0</td><td>88.0</td><td>760.0</td><td>10.0</td><td>15.0</td><td>1.79</td><td>5.1</td></tr>
</table>

Comparison with Solar and Wind Energy

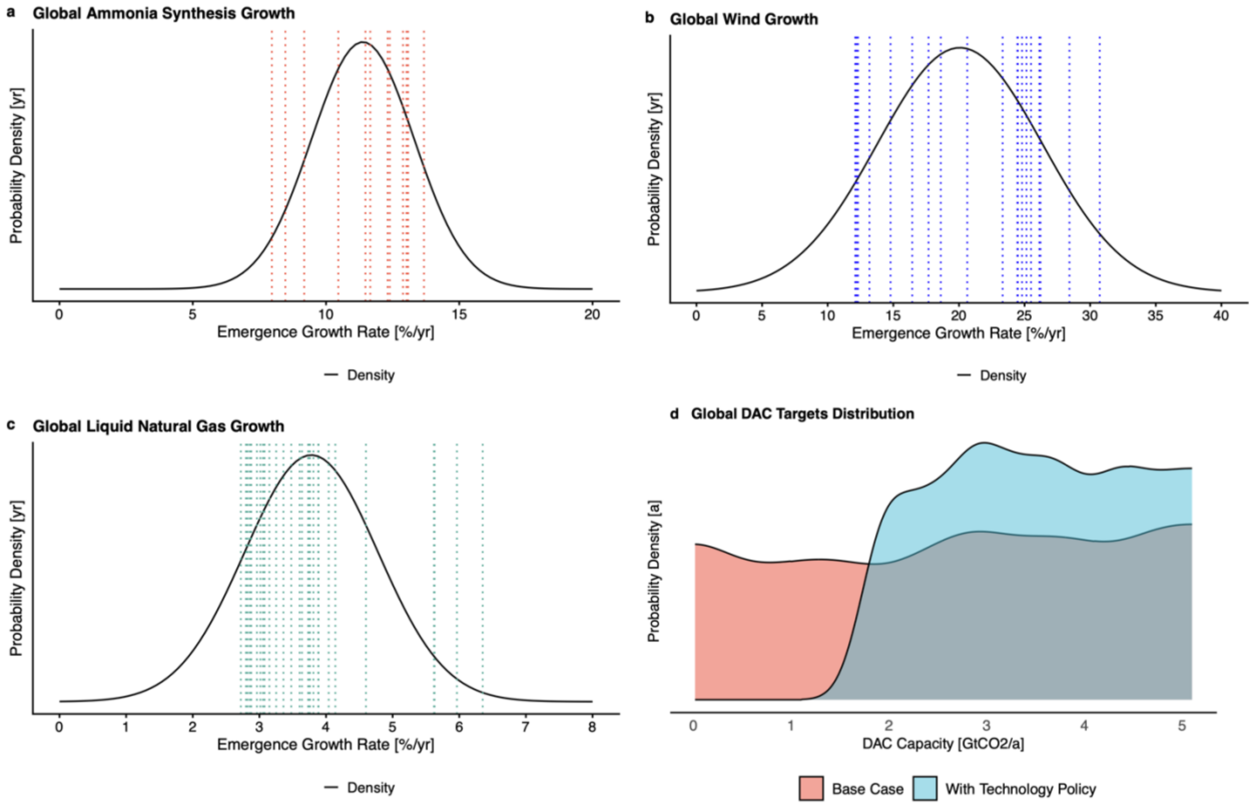
SI_Table 4: Comparison of DAC with solar and wind energy technologies.

Pro Arguments	**Contra Arguments**
Comparable Growth and Urgency	Complexity
As the rapid deployment of DAC is essential for meeting climate targets and maintaining them in the long term, this urgency could enable a similar scale-up as for wind energy during their boom phase. Both technologies are used for climate mitigation, so similar political measures must be taken to promote them [22,60].	DAC belongs to Type 3 technologies requiring specific technical capabilities, presenting barriers like learning-by-using, interproject spillovers, and technical complexity. Type 3 technologies rarely offer advantages for green industrial policies, unlike wind energy, which are Type 2 technologies with higher scalability and market volume [31].
Social Acceptance	General Coordination
Public opposition to DAC can hinder deployment, though the majority supports CDR for climate risk reduction [24]. Similar concerns exist for wind energy regarding landscape impact. Engaging communities and fostering understanding is critical for further deployment [25,61,62].	DAC requires simultaneous development of supply, demand, and infrastructure, demanding high coordination levels. Unlike wind energy, which benefit from established energy markets, DAC lacks such a foundation[17,22].
Political Support	International Agreements & Coordination
DAC deployment is backed by instruments like tax credits, subsidies, and RD&D funding, similar to support for wind [22]. Recent investments in DAC exceed $1 billion, comparable to early wind energy investments in the 1990s [22,63].	Despite project-level agreements for DAC under the Paris Agreement (Article 6), broader international collaboration is limited. Wind energy benefit from initiatives like Mission Innovation and numerous bilateral agreements [22].
Technology Development and Flexibility	Energy Demand
DAC costs are expected to decrease through innovation and scaling, following wind energy patterns. Its flexibility allows integration with planned CO_2 transport and storage infrastructure, enabling deployment in diverse locations [22,63].	DAC's energy demand, requiring 13 TW annually to meet Paris targets, raises concerns, accounting for over half of global energy supply [19]. Wind energy have shorter energy payback times and lower operational energy demands [64].

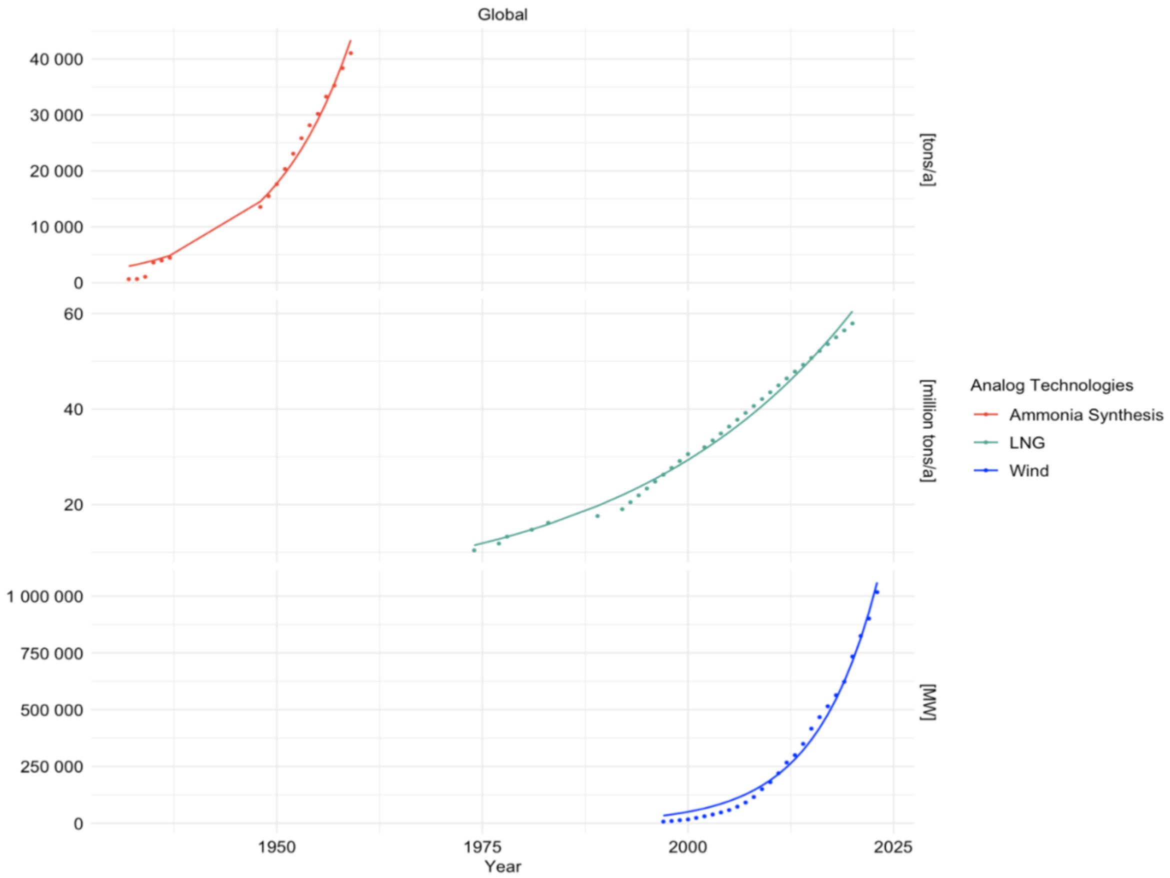
Additional Results

The following additional results of the considered emergence growth rates (exponentially fitted, see SI_Visual 4), ammonia synthesis as the baseline, LNG and wind energy as sensitivities, as well as of the long-term DAC demand form the basis for the modelling of the probabilistic feasibility spaces for the base case, as well as for the case with additional technology policy.

According to SI_Visual 3 the average emergence growth rate for ammonia synthesis is around 11%/a (a), for wind around 20%/a (b) and for LNG around 4%/a (c). The uniform distributions for the possible randomly selected DAC capacity targets and therefore for the determination of the long-term DAC demand (market growth) in (d) represents the mentioned minimum and maximum values for the base case and for the case with technology policy in the chapter 2.3.



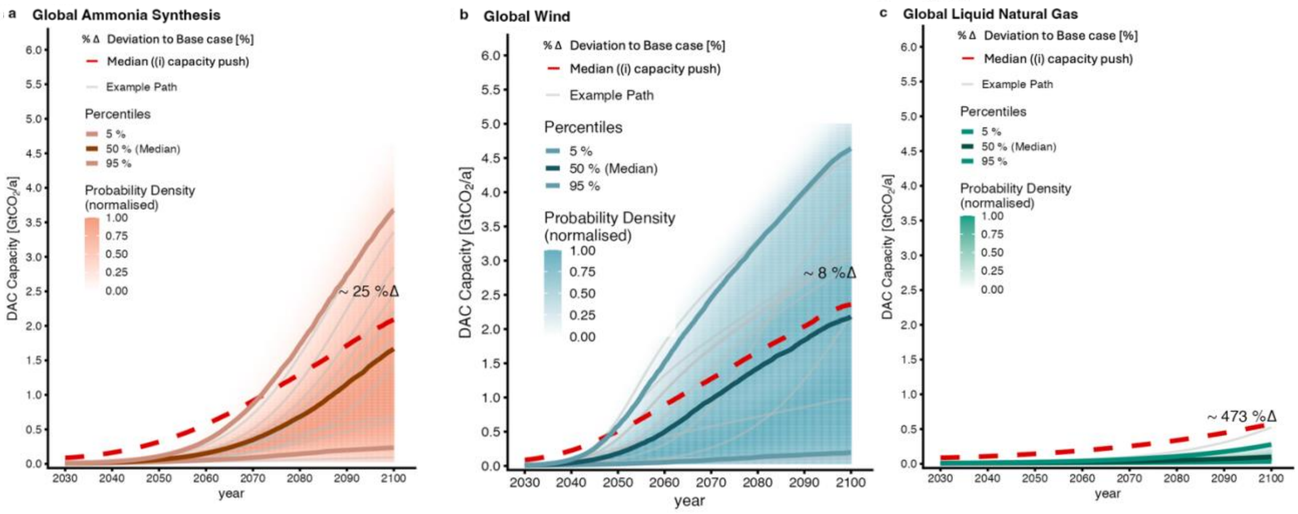
SI_Visual 3: (a-c): Probability distributions of the analysed global emergence growth rates, ammonia synthesis (a), and wind (b) as well as LNG (c) for sensitivity scenarios. The vertical dotted lines in (a-c) represents the 7-year moving intervals, which were determined through fitted exponential models (SI_Visual *4*) to the historical data of the analogs and with which the emergence growth rate distribution of the corresponding technologies was parametrised. (d) visualises the uniform distribution of the respective minimum and maximum values for the long-term market demand pull of the DAC capacity in 2050, with the distributions for the base case shown in red and the one with enhanced technology policy in blue.



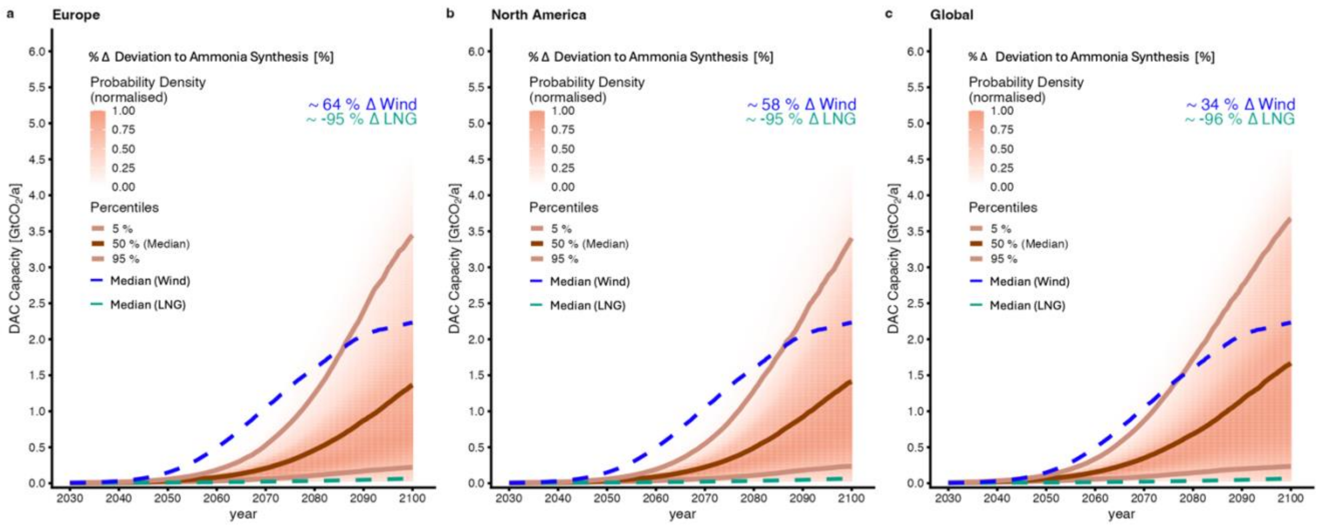
SI_Visual 4: Exponential growth phases used for ammonia synthesis in the period 1932 to 1959 (pink), LNG in the period 1974 to 2020 (brown) and wind energy in the period 1997 to 2023 (blue). The exponential models were fitted to the data for each technology at 7-year moving intervals by calculating the mean and standard deviation of the 7-year growth rates for each technology.

Extensive results for DAC deployment

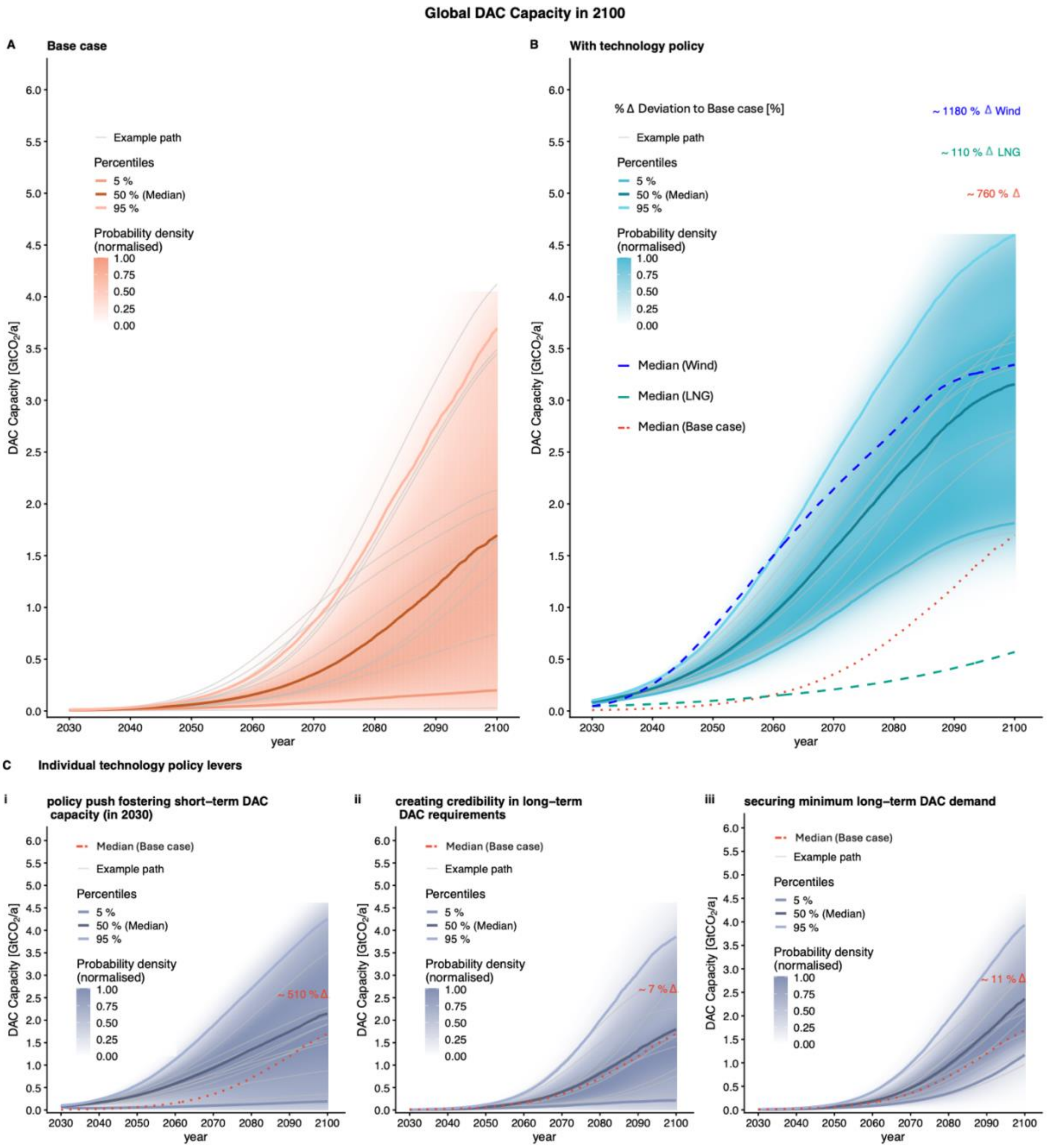
Additional results relating to our analysis are listed below. It should be noted that in all the analyses carried out and therefore presented in the main part (Visual 3), as well as in the supplementary information (SI_Visual 5SI_Visual 9), the percentage of deviation from the base case fluctuates minimally when running the code again (GitHub). However, this deviation is situated within a range that does not affect the main statement of the results and is therefore negligible.



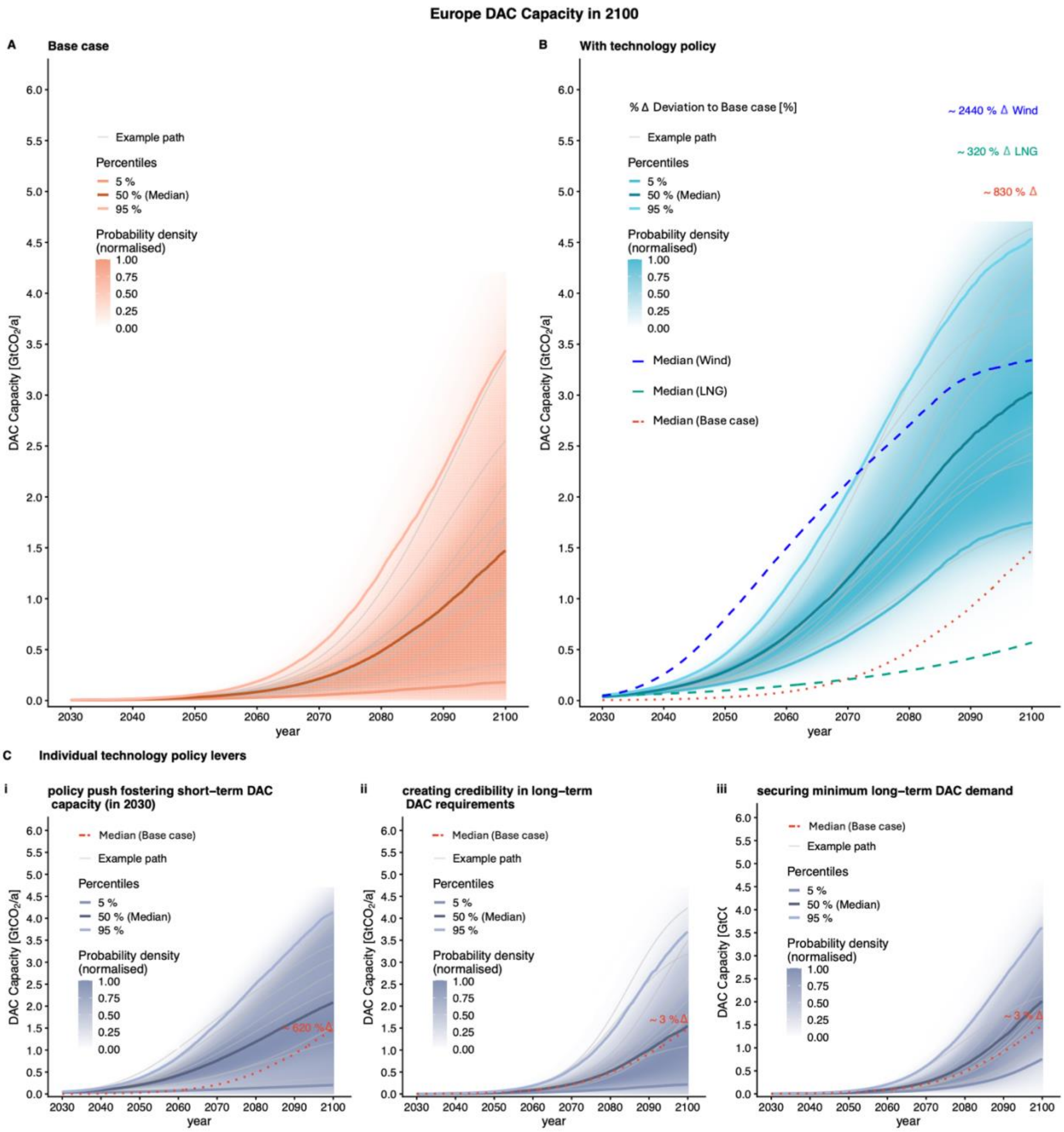
SI_Visual 5: Presentation of base case sensitivities results until 2100 for the technological analog ammonia synthesis, and the optimistic and pessimistic scenarios wind and LNG on the global level, together in comparison with the case with technology policy (i) their corresponding policy push (red).



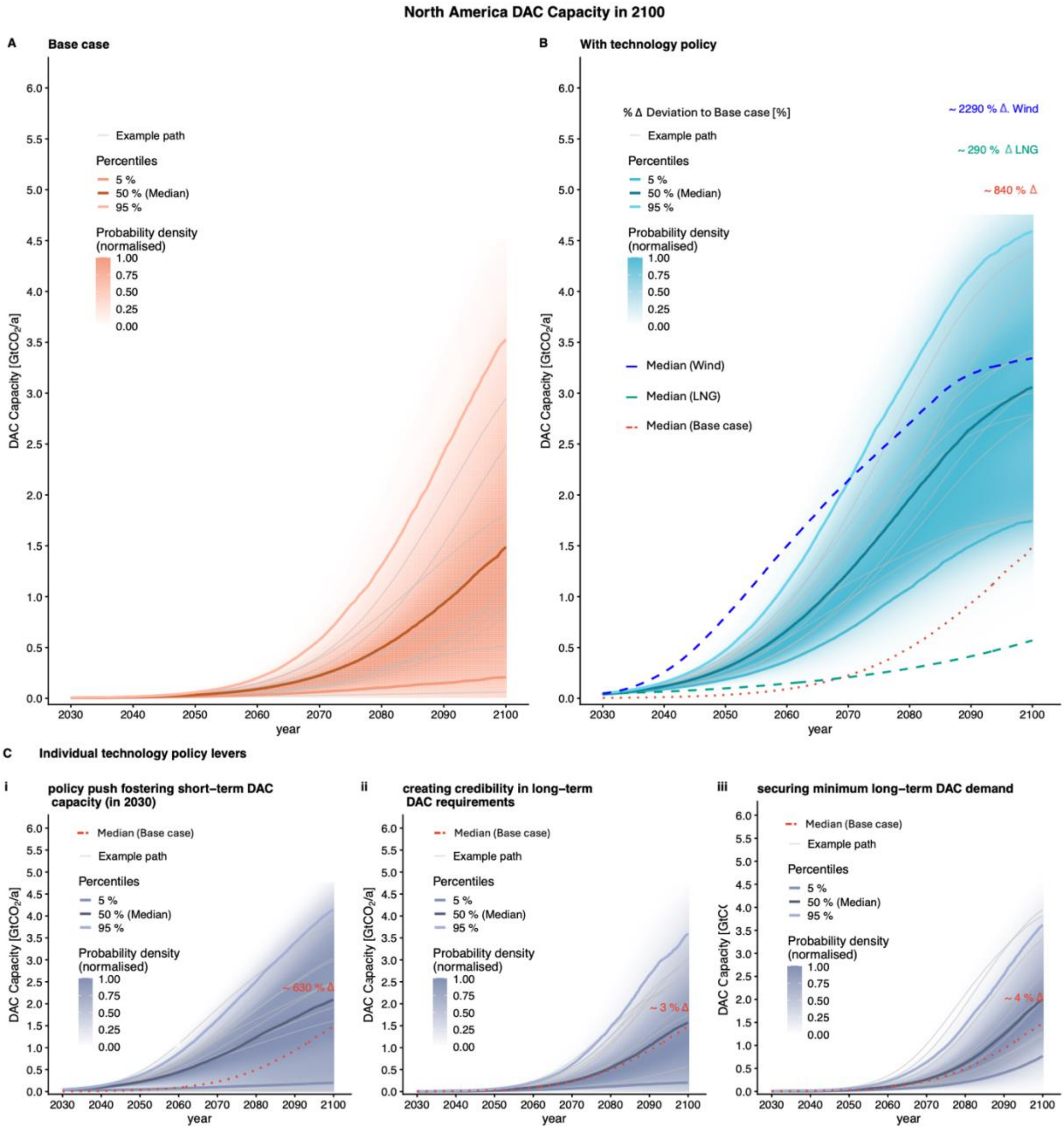
SI_Visual 6: Presentation of base case sensitivities results until 2100 for the technological analog ammonia synthesis, compared with the median path of the optimistic and pessimistic growth scenarios wind (blue) and LNG (green) on the regional level (North America and Europe).



SI_Visual 7: Probability feasibility space for achieving global DAC deployment by 2100, based on ammonia synthesis growth rates: (A) without policy support (base case) and (B) with policy support scenarios. Dashed lines compare optimistic (wind, blue) and pessimistic (LNG, green) analog growth rate sensitivities. Policy scenarios include (C): (i) a policy push to accelerate initial DAC capacity by 2030, (ii) measures to establish credible long-term DAC demand, and (iii) policies to secure minimum long-term demand. The color shading indicates the annual probability density (determined from the uncertainty propagation of the initial capacity in 2030 and the emergence growth rate), with grey lines showing example growth paths, representing the broad spectrum of possible outcomes. The deviation to the base case (% Δ) was rounded to the nearest 5th or 10th for all plots in A, B and C.



SI_Visual 8: Probability feasibility space for achieving regional DAC deployment by 2100 in Europe, based on ammonia synthesis growth rates: (A) without policy support (base case) and (B) with policy support scenarios. Dashed lines compare optimistic (wind, blue) and pessimistic (LNG, green) analog growth rate sensitivities. Policy scenarios include (C): (i) a policy push to accelerate initial DAC capacity by 2030, (ii) measures to establish credible long-term DAC demand, and (iii) policies to secure minimum long-term demand. The color shading indicates the annual probability density (determined from the uncertainty propagation of the initial capacity in 2030 and the emergence growth rate), with grey lines showing example growth paths, representing the broad spectrum of possible outcomes. The deviation to the base case (% Δ) was rounded to the nearest 5th, 10th for all plots in A, B and C.



SI_Visual 9: Probability feasibility space for achieving regional DAC deployment by 2100 in North America, based on ammonia synthesis growth rates: (A) without policy support (base case) and (B) with policy support scenarios. Dashed lines compare optimistic (wind, blue) and pessimistic (LNG, green) analog growth rate sensitivities. Policy scenarios include (C): (i) a policy push to accelerate initial DAC capacity by 2030, (ii) measures to establish credible long-term DAC demand, and (iii) policies to secure minimum long-term demand. The color shading indicates the annual probability density (determined from the uncertainty propagation of the initial capacity in 2030 and the emergence growth rate), with grey lines showing example growth paths, representing the broad spectrum of possible outcomes. The deviation to the base case (% Δ) was rounded to the nearest 5th or 10th for all plots in A, B and C.

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